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Subject: 2004 Montana Materials Manual Revisions

The Montana Materials Manual of Test Procedures has been revised to incorporate changes in content and procedure caused by changes in department specifications, national standards that affect the test procedures, and/or to correct any errors that have been detected in the present methods. The format of the procedures has also been changed for ease of use and a complete copy is being provided. Please remove and recycle the contents of the old Materials Manual and replace with the new version. Changes are in effect upon receipt.

It is not practical to list all the changes, so it is important that you review each procedure before use to acquaint yourself with any changes that may be in affect. The effective date of the changes is listed after the test procedure number and also in the header in the upper right-hand corner of each page. This copy has –04 included in all the test procedure headings and in the future will only be changed when a change in the procedure is required.

The following procedures have been added to the manual: MT-227, MT-232, MT-334, MT-335,

The following procedures have been removed from the manual: MT-221, MT-222, MT-224, MT-407, MT-408, MT-409, MT-415, MT-504, MT-507.

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July 2004

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TABLE OF CONTENTS
SAMPLING, INSPECTION, AND TESTING PROCEDURES

MT-100 SECTION (CONCRETE)

101 Making and Curing Compressive and Flexural Strength Test Specimens in the Field
102 Air Content of Freshly Mixed Concrete by the Pressure Method
103 Vacant
104 Slump of Portland Cement Concrete
105 Sampling Fresh Concrete
106 Measuring Length of Drilled Concrete Cores
107 Air Content of Freshly Mixed Concrete by the Volumetric Method
108 Sampling and Certification of Portland Cement
109 Method for Sampling Water
110 Reinforced Concrete Pipe and Associated Items
111 Sampling, Inspection and Reporting on Pre-stressed Concrete Beams and Piles
112 Vacant
113 Measuring the Texture Depth of Portland Cement Concrete Pavement
114 Sampling for Chloride Content of Bridge Deck Concrete
115 Weight Per Cubic Foot, Yield, and Air Content (Gravimetric)of Concrete

MT-200 SECTION (SOIL AND AGGREGATE)

200 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test
201 Sampling Roadway Materials
202 Sieve Analysis for Fine and Coarse Aggregate
203 Unit Weight of Aggregate
204 Specific Gravity and Absorption of Fine Aggregate
205 Specific Gravity and Absorption of Coarse Aggregate
206 Terms Relating to Density and Specific Gravity of Solids, Liquids and Gases
207 Centerline Soil Survey
208 Determining the Liquid Limit, the Plastic Limit, and the Plasticity Index of Soils
209 Los Angeles Abrasion (Wear Test)
210 Moisture-Density Relations of Soils Using a 5.5 lb Rammer and a 12 in. Drop
211 Moisture-Density Relations of Soil-Cement Mixtures
212 Determination of Moisture and Density in In-Place Materials
213 Plastic Fines in Graded Aggregates (Sand Equivalent Test)
214 The Classification of Soil and Soil-Aggregate Mixtures
215 Moisture Content by Calcium Carbide Method
216 Method of Sampling and Testing Cement Treated Base
217 Method for Determining Percentage of Mechanically Fractured Particles
218 Determining Relative Compaction and Percent Moisture
219 Controlling Compaction Using a Control-Strip Test-Section Technique with Nuclear Gauges
220 Specific Gravity of Soils
221 Vacant
222 Vacant
223 Clay Lumps and Friable Particles in Aggregates
224 Vacant
225 Failing and Check Samples of Aggregates
226 Maximum Acceptable Deviations in Sieve Analysis of IA Samples
227 Method of Test for Determination of Moisture Content of Soils
228 Method of Test for Evaluating Cleanness of Cover Coat Material
229 Procedure for Solids-Water-Voids Relations of Soil Masses

230 Moisture-Density Relation of Soils Using a 10 lb Rammer and 18 in Drop
231 Procedure for Correction for Coarse Particles in the Soil Compaction Test
232 Soil Corrosion Test

MT-300 SECTION (BITUMEN-AGGREGATE)

301 Sieve Analysis of Mineral Filler and Hydrated Lime
302 Sampling Bituminous Materials
303 Sampling Bituminous Paving Mixtures
304 Moisture Test of Plant-Mix Bituminous Aggregates
305 Volume Swell of Bituminous Mixtures
306 Marshall Method Mix Design
307 Centrifuge Extraction of Bituminous Mixtures
308 Temperature/Viscosity Charts
309 Reducing Samples of Hot Mix Asphalt to Testing Size
310 The Determination of Bituminous Aggregate Treatments
311 Marshall Method for Field Control of Hot Mix Asphalt Paving
312 Determining Moisture Content of Bituminous Mixtures
313 Procedure for Comparing Nuclear Gauge to Core Densities of Bituminous Paving Mixtures
314 Method of Test for Bulk Specific Gravity of Compacted Bituminous Mixtures
315 Bulk Specific Gravity of Compacted Bituminous Paving Mixtures Using Paraffin-Coated Specimens
316 Method of Sampling Recycled Pavement and Field Control of Recycle Paving
317 Procedure for Monitoring In-Place Bituminous Pavement Density and Air Voids
318 Using Dry Ice to Obtain Cores From Hot Plant Mix Surfacing
319 Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) by the Ignition Method
320 Mechanical Analysis of Aggregate Recovered from Ignition Oven Burn
321 Procedure for Determining Maximum Specific Gravity of Bituminous Paving Mixtures - "Rice Method"
322 Vacant
323 Fabricating Specimens for Compressive Strength of Bituminous Mixtures
324 Effect of Water on Cohesion of Compacted Bituminous Mixtures
325 Method of Determining Moisture Content of Bituminous Mixtures or Aggregate Using Microwave Ovens
326 Method of Sampling and Testing to Determine the Plane of Failure in Rutted Asphalt Pavements
327 Mechanical Analysis of Extracted Aggregate
328 Vacant
329 Procedure for Evaluating Plant Mix Surfacing Failures
330 Resistance of Compacted Bituminous Mixtures to Moisture Induced Damage
331 Method of Sampling and Evaluating Stripping Pavements
332 Gyratory Compaction of Bituminous Mixtures
333 Method of Test for the Torsional Recovery of Latex Modified Asphalt Emulsion Residue
334 Method of Test for Hamburg Wheel-Track Testing of Compacted Bituminous Mixtures
335 Linear Kneading Compaction of Bituminous Mixtures

MT-400 SECTION (MISCELLANEOUS)

401 Sampling and Inspecting Corrugated Aluminum Pipe
402 Sampling and Testing Corrugated Steel Pipe
403 Sampling and Inspection of Seeding and Landscaping Materials

404 Inspecting Wood Products
405 Wire Cloth Sieves for Testing Purposes
406 Sampling and Inspection of Signing Material and Signs
407 Vacant
408 Vacant
409 Vacant
410 Inspection, Sampling, Testing and Acceptance of Paint
411 Vacant
412 Topsoil Sampling, Sample Preparation and Testing
413 Inspection of Fencing Materials
414 Method of Acceptance for Reinforcing Steel
415 Vacant
416 Random Sampling Technique
417 Procedure for Reducing Field Samples to Testing Size
418 Method of Acceptance for Miscellaneous Welded Items
419 Method of Sampling and Sieve Analysis of Glass Beads
420 Procedure to Check for Leaks Under Hydrostatic Pressure
421 Sampling Construction Fabrics
422 Method of Test for Surface Smoothness and Profile

MT-500 SECTION (INFORMATION)

501 Definitions
502 Conversion Tables
503 Samples and Certifications
504 Vacant
505 Voids Table
506 Moisture Correction for Concrete Mix Designs
507 Vacant
508 Method of Figuring Yield of Concrete
509 Vacant
510 Field Numbering Concrete Cylinders
511 Terms Relating to Sub-grade, Soil Aggregate and Fill Materials
512 Numbering Sub-grade Material, Surfacing Material, Bituminous Treated Material and Liquid Asphalt
513 A Guide for Laboratory Forms

MT 600 SECTION (FIELD SAMPLING PROCEDURE)

601 Materials Sampling, Testing and Acceptance Guide-Index (English Version)
601 Materials Sampling, Testing and Acceptance Guide-Index (Metric Version)
602 Independent Assurance and Final Record Sampling

BACK

CURRENT DATE OF REVISION
MT-100 SECTION (CONCRETE)

Test Method No.	Title	Pages	Date of Publication or Revision
MT-101	Making and Curing Compressive and Flexural Strength Test Specimens in the Field	pp 1-8	May 2004
MT-102	Air Content of Freshly Mixed Concrete by the Pressure Method	pp 1-8	May 2004
MT-103	Vacant		
MT-104	Slump of Portland Cement Concrete	pp 1-3	May 2004
MT-105	Sampling Fresh Concrete	pp 1-3	May 2004
MT-106	Measuring Length of Drilled Concrete Cores	pp 1-2	May 2004
MT-107	Air Content of Freshly Mixed Concrete by the Volumetric Method	pp 1-4	May 2004
MT-108	Sampling and Certification of Portland Cement	pp 1-2	May 2004
MT-109	Method for Sampling Water	pp 1	May 2004
MT-110	Reinforced Concrete Pipe and Associated Items	pp 1-3	May 2004
MT-111	Sampling, Inspection and Reporting on Prestressed Concrete Beams and Piles	pp 1-3	May 2004
MT-112	Vacant		
MT-113	Measuring the Texture Depth of Portland Cement Concrete Pavement	pp 1-2	May 2004
MT-114	Sampling for Chloride Content of Bridge Deck Concrete	pp 1-3	May 2004
MT-115	Weight Per Cubic Foot, Yield, and Air Content (Gravimetric) of Concrete	pp 1-5	May 2004

METHODS OF SAMPLING AND TESTING
MT 101-04
MAKING AND CURING CONCRETE COMPRESSIVE AND FLEXURAL STRENGTH TEST SPECIMENS IN THE FIELD
(Modified AASHTO T23 and M205)

1 Scope:

1.1 This method covers procedures for making and curing cylindrical and prismatic specimens using job concrete that can be consolidated by rodding or vibration as described herein.

1.2 The concrete used to make the molded specimens shall have the same level of slump, air content, and percentage of coarse aggregate as the concrete being placed in the work.

1.3 The values stated in inch-pound units are to be regarded as the standard. The metric equivalents given in the standard may be approximate.

1.4 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Referenced Documents:

2.1 ***AASHTO:***
M 205 Molds for Forming Concrete Test Cylinders Vertically
T 23 Making and Curing Concrete Test Specimens in the Field
T 141 Sampling Freshly Mixed Concrete

MT Materials Manual:
MT-102 Air Content of Freshly Mixed Concrete by the Pressure Method
MT-104 Slump of Portland Cement Concrete
MT-105 Sampling Fresh Concrete
MT-107 Air Content of Freshly Mixed Concrete by the Volumetric Method
MT-510 Field Numbering Concrete Cylinders

3 Apparatus:

3.1 *Molds, General*--Molds for specimens or fastenings thereto in contact with the concrete shall be made of steel, cast iron, or other nonabsorbent material, nonreactive with concrete containing portland or other hydraulic cements. Molds shall hold their dimensions and shape under conditions of severe use. Molds shall be watertight during use as judged by their ability to hold water poured into them. A suitable sealant, such as heavy grease, modeling clay, or microcrystalline wax, shall be used where necessary to prevent leakage through the joints. Positive means shall be provided to hold base plates firmly to the molds. Molds shall be lightly coated with mineral oil or a suitable reactive form release material before use.

Note 1 - Single use molds (plastic, cardboard, tin) are not acceptable for use to cast concrete cylinders for acceptance samples. Single use molds are permitted for field cured cylinders used to determine false work removal, opening to traffic, etc.

3.2 *Reusable Vertical Molds*--Molds shall be constructed in the form of right circular cylinders which stand with the cylindrical axis vertical and the top open to receive the concrete. They shall have a nominal inside height equal to twice the nominal inside diameter. The average diameter of a mold shall not differ from the nominal diameter by more than 1 percent and no individual diameter shall differ from any other diameter by more than 2 percent. The plane of the rim of the mold and the

3 **Apparatus:** (continued)

bottom shall be perpendicular to the axis of the mold within 0.5 degrees (approximately equivalent to 1/8 in. in 12 in. or 3 mm. in 305 mm.). The molds must be provided with a closure or base on the lower end at right angles at the axis of the cylinder. The base will consist of a separate base plate and a means of attaching it to the cylindrical side walls. In preparation for use, the assembled mold and base plate shall be coated with a material that will prevent adherence to the concrete.

3.3 *Beam Molds*--Beam molds shall be rectangular in shape and or the dimensions required to produce the specimens stipulated in Section 4.2. The inside surfaces of the molds shall be smooth. The sides, bottom, and ends shall be at right angles to each other and shall be straight and true and free of warpage. Maximum variation from the nominal cross section shall not exceed 1/8 in. (3.2 mm) for molds with depth or breadth of 6 in. (152 mm) or more. Molds shall produce specimens not more than 1/16 in. (1.6 mm) shorter than the required length in accordance with Section 4.2, but may exceed it by more than that amount.

3.4 *Tamping Rods*--Two sizes are specified in Table 1. Each shall be a round, straight steel rod with at least the tamping end rounded to a hemispherical tip of the same diameter as the rod. Both ends may be rounded if preferred.

Table 1 – Tamping Rod Requirements

	Rod Dimensions*	
Diameter of Cylinder or Width of Beam, In. (mm)	Diameter, in. (mm)	Length of Rod, in. (mm)
<6 (150)	3/8 (10)	12 (300)
6 (150)	5/8 (16)	20 (500)
9 (225)	5/8 (16)	26 (650)

**Rod tolerances length ± 4 in. (100 mm) and diameter ± 1/16 in (2 mm).*

3.4.1 *Large Rod*--5/8 in. (16 mm) in diameter and approximately 24 in. (610 mm) long.

3.4.2 *Small Rod*--3/8 in. (10 mm) in diameter and approximately 12 in. (305 mm) long.

3.5 *Vibrators*--Internal vibrators may have rigid or flexible shafts, preferably powered by electric motors. The frequency of vibration shall be 7,000 vibrations per minute or greater while in use. The diameter of a round vibrator shall be no more than one-forth the diameter of the cylinder mold or one-forth the width of the beam mold. Other shaped vibrators shall have a perimeter equivalent to the circumference of an appropriate round vibrator.The combined length of the shaft and vibrating element shall exceed the depth of the section being vibrated by at least 3 in. (76 mm).

3.6 *Mallet*--A mallet with a rubber or rawhide head weighing 1.25 ± 0.50 lb (0.57 ± 0.23 kg) shall be used.

3.7 *Small Tools*--Tools and items which may be required are shovels, pails, trowels, wood float, metal float, blunted trowels, straightedge, feeler gage, scoops, and rules.

3.8 *Slump Apparatus*--The apparatus for measurement of slump shall conform to the requirements of Method MT-104.

3.9 *Sampling and Mixing Receptacle*--The receptacle shall be a suitable heavy gage metal pan, wheelbarrow, or flat, clean, nonabsorbent mixing board of sufficient capacity to allow easy remixing of the entire sample with a shovel or trowel.

3.10 *Air Content Apparatus*--The apparatus for measuring air content shall conform to the requirements of Methods MT-107 or MT-102.

4 Test Specimens:

4.1 *Compressive Strength Specimens*--Compressive strength specimens shall be cylinders of concrete cast and hardened in an upright position, with a length equal to twice the diameter. The standard specimen shall be the 6 by 12 in. (150 by 300 mm) cylinder when the maximum size of the coarse aggregate does not exceed 2 in. (50 mm), either the concrete sample shall be treated by wet sieving as described in AASHTO T 141 or the diameter of the cylinder shall be at least three times the nominal maximum size of the coarse aggregate in the mixture. The specimens may be 4 by 8 in. (100 by 200 mm) cylinders when the nominal maximum size of the coarse aggregate does not exceed 1 in. (25 mm).

4.2 *Flexural Strength Specimens*--Flexural strength specimens shall be rectangular beams of concrete cast and hardened with long axes horizontal. The length shall be at least 2 in. (50 mm) greater than three times the depth as tested. The ratio of width to depth as molded shall not exceed 1.5. The standard beam shall be 6 by 6 in. (152 by 152 mm) in cross section, and shall be used for concrete with a nominal maximum size coarse aggregate up to 2 in. (50 mm). When the nominal maximum size of the coarse aggregate exceeds 2 in. (50 mm), the smaller cross-sectional dimension of the beam shall be at least three times the nominal maximum size of the coarse aggregate. Unless required by the project specifications, beams made in the field shall not have a width or depth of less than 6 in.

5 Sampling Concrete:

5.1 The samples used to fabricate test specimens under this standard shall be obtained in accordance with Method MT-105 unless an alternative procedure has been approved.

5.2 Record the identity of the sample with respect to the location of the concrete represented and the time of casting.

6 Slump, Air Content, and Temperature:

6.1 *Slump*--Measure the slump of each batch of concrete, from which specimens are made, immediately after remixing in the receptacle as required in Method MT-104.

6.2 *Air Content*--Determine the air content in accordance with either Method MT-102 or Method MT-107. The concrete used in performing the air content test shall not be used in fabricating test specimens.

7 Molding Specimens:

7.1 *Place of Molding*--Mold specimens promptly on a level, rigid, horizontal surface, free from vibration and other disturbances, at a place as near as practicable to the location where they are to be stored.

7.2 *Placing the Concrete*--Place the concrete in the molds using a scoop, blunted trowel, or shovel. Select each scoopful, trowelful, or shovelful of concrete from the mixing pan to ensure that it is representative of the batch. Remix the concrete in the mixing pan with a shovel or trowel to prevent segregation during the molding of specimens. Move the scoop, trowel, or shovel around the perimeter of the mold opening when adding concrete to ensure an even distribution of the concrete and to minimize segregation. Further distribute the concrete by use of a tamping rod prior to the start of consolidation. In placing the final layer, the operator shall attempt to add an amount of concrete that will exactly fill the mold after compaction. Do not add non-representative concrete to an under filled mold.

7.2.1 *Number of Layers*--Make specimens in layers as indicated in Tables 2 or 3.

Table 2 – Molding Requirements by Rodding

Specimen Type and Size	Number of Layers of Approximately Equal Depth	Number of Roddings per Layer
Cylinders:		
Diameter in. (mm)		
4 (100)	2	25
6 (150)	3	25
9 (225)	4	50
Beams:		
Width in. (mm)		
6 (150 to 8 (200)	2	Sec 7.3.2
>8 (over 200)	3 or more equal depths, each not to exceed 6 in. (150 mm)	Sec 7.3.2

Table 3 – Molding Requirements by Vibration

Specimen Type and Size	Number of layers	Number of Vibrator Insertions per Layer	Approximate Depth of Layer, in. (mm)
Cylinders:			
Diameter, in. (mm)			
4 (100)	2	1	one-half depth of specimen
5 (150)	2	2	one-half depth of specimen
9 (225)	2	4	one-half depth of specimen
Beams:			
Width in. (mm)			
6 (150 to 8 (200)	1	Sec 7.4.2	depth of specimen 8 (200) as near as practicable
over 8 (200)	2 or more	Sec 7.4.2	depth of specimen 8 (200) as near as practicable

7.2.2 Select the proper tamping rod from section 3.4 and Table 1 or the proper vibrator from Section 3.5. If the method of consolidation is rodding, determine the molding requirements from Table 2. If the method if consolidation is vibration, determine the molding requirements from Table 3.

7.3 *Consolidation:*

7.3.1 *Methods of Consolidation*--Preparation of satisfactory specimens requires different methods of consolidation. The methods of consolidation are rodding, and internal or external vibration. Base the selection of the method of consolidation on the slump, unless the method is stated in the specifications under which the work is being performed. Rod concrete with a slump greater than 3 in. (75 mm). Rod or vibrate concretes with slump of 1 to 3 in. (25 to 75 mm). Vibrate concretes with slump of less than 1 in. (25 mm).

7.3.2 *Rodding*--Place the concrete in the mold, in the required number of layers of approximately equal volume. For cylinders, rod each layer with the rounded end of the rod using the number of strokes specified in Table 2. The number of roddings per layer required for beams is one for each 2 in.^{2} (13 cm^2) top surface area of the specimen. Rod the bottom layer throughout its depth. Distribute the strokes uniformly over the cross section of the mold and for each upper layer allow the rod to

7.3 *Consolidation:* (continued)

penetrate about ½ in. (12 mm) into the underlying layer when the depth of the layer is less than 4 in. (100 mm), and about 1 in. (25 mm) when the depth is 4 in. or more. After each layer is rodded, tap the outsides of the mold lightly 10 to 15 times with the mallet, to close any holes left by rodding and to release any large air bubbles that may have been trapped. Tap light-gage single-use molds, susceptible to damage if tapped with the mallet, using an open hand. After tapping, spade the concrete along the sides and ends of beam molds with a trowel or other suitable tool.

7.3.3 *Vibration*--Maintain a uniform time period for duration of vibration for the particular kind of concrete, vibrator, and specimen mold involved. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator. Usually, sufficient vibration has been applied as soon as the surface of the concrete has become relatively smooth. Continue vibration only long enough to achieve proper consolidation of the concrete. Over-vibration may cause segregation. Fill the molds and vibrate in the required number of approximately equal layers. Place all the concrete for each layer in the mold before starting vibration of that layer. When placing the final layer, avoid overfilling by more than 1/4 in. (6 mm). Finish the surface either during or after vibration where external vibration is used. Finish the surface after vibration when internal vibration is used. When the finish is applied after vibration, add only enough concrete with a trowel to overfill the mold about 1/8 in. (3 mm). Work it into the surface and then strike it off.

7.3.3.1 *Internal Vibration*--The diameter of the vibrating element, or thickness of a square vibrating element, shall be in accordance with the requirements of Section 3.5. For beams, the vibrating element shall not exceed _ of the width of the mold. For cylinders, the ratio of the diameter of the cylinder to the diameter of the vibrating element shall be 4.0 or higher. In compacting the specimen, the vibrator shall not be allowed to rest on the bottom or sides of the mold. Carefully withdraw the vibrator in such a manner that no air pockets are left in the specimen.

7.3.3.2 *Cylinders*--Use three insertions of the vibrator at different points for each layer. Allow the vibration to penetrate through the layer being vibrated, and into the layer below, approximately 1 in. (25 mm). After each layer is vibrated, tap the outsides of the mold lightly 10 to 15 times with the mallet, to close any holes left by vibrating and to release any large air bubbles that may have been trapped. Use an open hand to tap light-gage single use molds that are susceptible to damage if tapped with a mallet.

7.3.3.3 *Beam*--Insert the vibrator at intervals not exceeding 6 in. (150 mm) along the centerline of the long dimension of the specimen. For specimens wider than 6 in., use alternating insertions along two lines. Allow the shaft of the vibrator to penetrate into the bottom layer approximately 1 in. (25 mm). After each layer is vibrated, tap the outsides of the mold lightly 10 to 15 times with the mallet, to close any holes left by vibrating and to release any large air bubbles that may have been trapped.

7.3.4 *External Vibration*--When external vibration is used, take care to ensure that the mold is rigidly attached to or securely held against the vibrating element or vibrating surface.

7.4 *Finishing*--After consolidation, unless the finishing has been performed during the vibration (7.3.3), strike off the surface of the concrete and flat or trowel it as required. Perform all finishing with the minimum manipulation necessary to produce a flat even surface that is level with the rim or edge of the molds and that has no depressions or projections larger than 1/8 in. (3mm).

7.4.1 *Cylinders*--After consolidation, finish the top surfaces by striking them off with the tamping rod where the consistency of the concrete permits or with a wood float or trowel.

7.4.2 *Beams*--After consolidation of the concrete, strike off the top surface to the required tolerance to produce a flat even surface. A wood float may be used.

7 Molding Specimens: (continued)

7.5 *Initial Storage*--Immediately after being struck off, the specimens shall be moved to the storage place where they will remain undisturbed for the initial curing period. If specimens made in single use mold are moved, lift and support the specimens from the bottom of the molds with a large trowel or similar device.

8 Curing:

8.1 *COVERING AFTER FINISHING* - To prevent evaporation of water from the unhardened concrete, the specimens shall be covered immediately after finishing, preferably with a non-absorptive, non-reactive plate or a sheet of tough, durable, impervious plastic.

8.2 *Curing Specimens for Checking the Adequacy of Laboratory Mixture Proportions for Strength or as the Basis for Acceptance or Quality Control.*

8.3 *INITIAL CURING* – After molding, the specimens shall be stored in a temperature range between 60º to 80ºF (16º to 27ºC), and in a moist environment preventing any loss of moisture up to 48 hours (Note 2). At all times the temperature in and between specimens shall be controlled by shielding from direct rays of the sun and radiant heating devices. Specimens that are to be transported to the laboratory for standard curing (Section 9.2.1) before 48 hours shall remain in the molds in a moist environment, until they are received in the laboratory, de-molded and placed in standard curing. If specimens are not transported within 48 hours, the mold shall be removed within 24 ± 8 hours and standard curing used until transported. See section 10.1).

Note 2 - It may be necessary to create an environment during initial curing to provide satisfactory moisture and to control the temperature. The specimens may be immersed immediately in saturated limewater, and/or stored in tightly constructed wooden boxes, damp sand pits, temporary buildings at construction sites, under wet burlap, or in heavyweight closed plastic nags. Immersing in saturated limewater is not acceptable for specimens in cardboard or other molds that expand when immersed in water. Other suitable methods may be used provided the foregoing requirements limiting specimen temperature and moisture loss are met. The temperature may be controlled by ventilation, or thermostatically controlled cooling devices, or by heating devices such as stoves, light bulbs, or thermostatically controlled heating elements. Temperature record of the specimens may be established by means of maximum-minimum thermometers. Early age results may be lower when stored near 60ºF (16ºC) and higher when stored near 80ºF (27ºC).

8.4 STANDARD CURING:

8.4.1 Cylinders – Upon completion of initial curing and within 30 minutes after removing the molds, store specimens in a moist condition with free water maintained on their surfaces at all times at a temperature of 73.4±3ºF (23 ± 1.7ºC). Temperatures between 68º and 86ºF (20º and 30ºC) are permitted fro a period not to exceed 3 hours immediately prior to test if free moisture is maintained on the surfaces of the specimen at all times, except when capping with sulfur mortar capping compound. When capping with this material, the ends of the cylinder will be dried as described in AASHTO T 231. Specimens shall not be exposed to dripping or running water. The required moist storage can be obtained by immersion in saturated limewater and may be obtained by storage in a moist room or cabinet meeting the requirements of AASHTO M 201.

8.4.2 Beams – Beams are to be cured the same as cylinders (Section 10.1) except for a minimum of 20 hours prior to testing, they shall be stored in saturated limewater at 73.4º±3ºF (23±1.7ºC). Drying of the surfaces of the beam shall be prevented between removal from the limewater and completion of testing. (Note 3)

Note 3 - Relatively small amounts of drying of the surface of flexural specimens induce tensile stresses in the extreme fibers that will markedly reduce the indicated flexural strength.

9 Curing Specimens for Checking the Adequacy of Laboratory Mixture Proportions for Strength or as the Basis for Acceptance or Quality Control at Remote Sites:

9.1 Specimens prepared and stored at remote sites, which do not have facilities for controlling temperature with the tolerance of 73.4°±3°F (23±1.7°C) shall be cured in accordance with the provisions of Section 9.2 except as modified by Section 9.3.

9.2 *Initial Curing at Remote Sites* – Specimens shall be cured in accordance with Section 8.

9.2.1 Specimens that will not be transported or are to be transported after 48 hours age may be cured without demolding provided that loss of moisture is prevented in accordance with section 8 until the time of transportation or testing.

9.3 *Standard Curing at Remote Sites* – Specimens to be stored at a remote site and shipped to a laboratory for test or to be tested at the remote site shall be cured in accordance with Sections 9.1, 9.2,and 9.2.1 until the time of shipment or test. Specimens shall not be exposed dripping or running water.

9.3.1 Beam specimens to be stored at remote sites shall be cured in accordance with Section 9, except for a minimum of 20 hours before testing, they shall be stored in saturated lime water at 60° to 80°F (16° to 27°C). Drying of the surfaces of the beam shall be prevented between removal from the limewater and completion of testing. (Note 4).

Note 4 – Curing of specimens at remote sites in accordance with Section 9 may yield significantly different results as compared to specimens cured in accordance with Section 8.2.

10 Curing for Form Removal Time or When a Structure May be Put into Service:

10.1 *Cylinders* – Store cylinders in or on the structure as near to the point of deposit of the concrete represented as possible. Protect all surfaces of the cylinders from the elements in as near as possible the same way as the formed work. Provide the cylinders with the same temperature and moisture environment as the structural work. Test the specimens in the moisture condition resulting from the specified moisture treatment. To meet these conditions, specimens made for the purpose of determining when a structure may be put in service shall be removed from the molds at the time of removal of formwork.

10.2 *Beams* – As nearly as practicable, cure beams in the same manner as the concrete in the structure. At the end of 48 ± 4 hours after molding, take the molded specimens to the storage location and remove from the molds. Store specimens representing pavements or slabs on grade by placing them on the ground as molded, with their top surfaces up. Bank the side and ends of the specimens with earth or sand that shall be kept damp, leaving the top surfaces exposed to the specified curing treatment. Store specimens representing structural concrete as near to the point in the structure they represent as possible and afford them the same temperature protection and moisture environment as the structure. At the end of the curing period leave the specimens in place exposed to the weather in the same manner as the structure. Remove all beam specimens from field storage and store in limewater at 73.4 ± 5°F (23 ± 2.8°C) for 24 ± 4 hours immediately before time of testing to ensure uniform moisture condition from specimen to specimen. Observe the precautions given in Section 8.4.2 to guard against drying between time of removal from curing to testing.

11 Shipment to Laboratory:

11.1 Cylinders and beams shipped from the field to the laboratory for testing shall be packed in sturdy wooden boxes supplied by the Materials Bureau, surrounded by wet sawdust and protected from freezing during shipment. Upon receipt by the laboratory, cylinders shall be capped and immediately placed in the moist room. The shipper shall fill out Laboratory Form No. 93 and place

11 Shipment to Laboratory: (continued)

one copy in the plastic envelope supplied, to accompany the cylinder, mail one copy to the Materials Bureau, and retain one copy for the shipper's file.

11.2 Test specimens shall not be shipped from the field until at least three days after casting.

11.3 Retaining the cylinders on the project for three days will permit sufficient strength to develop to greatly reduce the possibility of latent damage from rough handling or exposure to low temperatures during shipping. Past cylinder failure investigations have produced considerable evidence that such latent damage may be a major factor in low-test cylinder strengths. This is particularly evident where cylinders have been removed from the molds and shipped the day after casting during periods of below freezing weather.

11.4 It is realized that, in some cases, retaining the cylinders on the project for three days may result in the first cylinder being tested later than the specified seven days. However, a late seven-day test is preferable to the possibility of damaging the entire set by shipping before adequate strength is developed. Every effort should be made, however, to comply with paragraph 8.3 above in order that the specimen will receive the 24-hour curing in the moist room in the Materials Bureau.

12 Preparation of Laboratory Form No. 93:

12.1 Form No. 93, which accompanies each cylinder, should be completed with extreme care, paying particular attention to the date when the cylinders were made. The mix design, water and air content, cement certification and the laboratory numbers of the aggregates being used should be checked to make certain they are correct and they should be changed whenever new project mixes, laboratory numbers or other information is available. Project numbers should be accurate and complete including unit numbers and the correct termini should be shown. Special attention is directed to MT-510, Field Numbering Concrete Cylinders.

METHODS OF SAMPLING AND TESTING
MT 102-04
METHOD OF DETERMINING AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE PRESSURE METHOD
(Modified AASHTO T152)

1 Scope:

1.1 This method covers determination of the air content of freshly mixed concrete from observation of the change in volume of concrete with a change in pressure.

1.2 This method is intended for use with concretes and mortars made with relatively dense aggregates. It is not applicable to concretes made with lightweight aggregates, air-cooled blast-furnace slag, or aggregates of high porosity.

2 Reference Document:

2.1 ***AASHTO:***
T121 Mass per Cubic Meter (Cubic Foot), Yield, and Air Content (Gravimetric) of Concrete
T152 Air Content of Freshly Mixed Concrete by the Pressure Method

MT. Materials Manual:
MT-105 Sampling Freshly Mixed Concrete

3 Apparatus:

3.1 *Air Meter* - There are two basic operational designs available employing the principle of Boyle's law. For purposes of reference, these will be designated Type A Meter and Type B Meter.

3.1.1 *Type A Meter* - An air meter consisting of a measuring bowl and cover assembly (see Figure 1) conforming to the requirements of Sections 3.2 and 3.3. The operational principle of this meter consists of introducing water to a predetermined height above a sample of concrete of known volume, and the application of a predetermined air pressure over the water. The determination consists of the reduction in volume of the air in the concrete sample by observing the amount the water level is lowered under the applied pressure, the latter amount being calibrated in terms of percent of air in the concrete sample.

3.1.2 *Type B Meter* - An air meter consisting of a measuring bowl and cover assembly (see Figure 2) conforming to the requirements of Section 3.2 and 3.3. The operational principle of this meter consists of equalizing a known volume of air at a known pressure in a sealed air chamber with the unknown volume of air in the concrete sample, the dial on the pressure gage being calibrated in terms of percent air for the observed pressure at which equalization takes place. Working pressures of 7.5 to 30.0 psi (51 to 207 kPa) having been used satisfactorily.

3.2 *Measuring Bowl* - The measuring bowl must be essentially cylindrical in shape, made of steel, hard metal, or other hard material not readily attacked by the cement paste, having a minimum diameter equal to 0.75 to 1.25 times the height, and a capacity of at least 0.20 ft^3 (0.006 m^3). It must be flanged or otherwise constructed to provide for a pressure tight fit between the bowl and cover assembly. The interior surfaces of the bowl and surfaces of rims, flanges and other component fitted parts must be machined smooth. The measuring bowl and cover assembly must be sufficiently rigid to limit expansion of the apparatus assembly to not more than 0.1 percent of air content on the indicator scale when under normal operating pressure.

3 **Apparatus:** (continued)

3.3 **Cover Assembly:**

3.3.1 The cover assembly shall be made of steel or other hard metal not readily attacked by the cement paste. It must be flanged or otherwise constructed to provide for a pressure-tight fit between bowl and cover assembly and must have machined smooth interior surfaces contoured to provide an air space above the level of the top of the measuring bowl. The cover must be sufficiently rigid to limit the expansion factor of the apparatus assembly as prescribed in 3.2.

3.3.2 The cover assembly must be fitted with a means for direct reading of the air content. The cover for the Type A meter must be fitted with a standpipe, which may be a transparent graduated tube or may be a metal tube of uniform bore with a glass water gage attached. In the Type B meter, the dial of the pressure gage must be calibrated to indicate the percent of air. Graduations must be provided for a range in air content of at least 8 percent easily readable to 0.1 percent as determined by the proper air pressure calibration test.

3.3.3 The cover assembly shall be fitted with air valves, air bleeder valves, and petcocks for bleeding off or through which water may be introduced as necessary for the particular meter design. Suitable means for clamping the cover to the bowl shall be provided to make a pressure-tight seal without entrapping air at the joint between the flanges of the cover and bowl. A suitable hand pump shall be provided with the cover either as an attachment or as an accessory.

3.4 *Calibration Vessel* - A measure having an internal volume equal to a percent of the volume of the measuring bowl corresponding to the approximate percent of air in the concrete to be tested; or, if smaller, it shall be possible to check calibration of the meter indicator at the approximate percent of air in the concrete to be tested by repeated filling of the measure. When the design of the meter requires placing the calibration vessel within the measuring bowl to check calibration, the measure shall be cylindrical in shape and of an inside depth 1/2 in. (13 mm) less than that of the bowl. A satisfactory measure of this type may be machined from No. 16 gage brass tubing, of a diameter to provide the volume desired, to which a brass disk 1/2 in. in thickness is soldered to form an end. When design of the meter requires withdrawing of water from the water-filled bowl and cover assembly to check calibration, the measure may be an integral part of the cover assembly or may be a separate cylindrical measure similar to the above described cylinder.

3.5 The designs of various available types of airmeters are such that they differ in operating techniques and therefore, all of the items described in 3.6 through 3.14 may not be required. The items required must be those necessary for use with the particular design of apparatus used to satisfactorily determine air content in accordance with the procedures prescribed herein.

3.6 *Spray Tube* - A brass tube of appropriate diameter, which may be an integral part of the cover assembly or which may be provided separately. It must be so constructed that when water is added to the container, it is sprayed to the walls of the cover in such a manner as to flow down the sides causing a minimum of disturbance to the concrete.

3.7 *Trowel* - A standard brick mason's trowel.

3.8 *Tamping Rod* - The tamping rod shall be a round, straight steel rod 5/8 in. (16 mm) in diameter and approximately 24 in. (600 mm) in length, having the tamping end rounded to a hemispherical tip the diameter of which is 5/8 in.

3.9 *Mallet* - A mallet (with a rubber or rawhide head) weighing approximately 1.25 ± 0.50 lb. (0.57 ± 0.23 kg) for use with measures of 0.5 $ft.^3$ (14 dm^3) or smaller, and a mallet weighing approximately 2.25 ± 0.50 lb. (1.02 ± 0.23 kg) for use with measures larger than 0.5 $ft.^3$.

3.10 *Strike-Off Bar* - A flat straight bar of steel or other suitable metal at least 1/8 in. (3 mm) thick and 3/4 in. (20 mm) wide by 12 in. (300 mm) long.

3 Apparatus: (continued)

3.11 *Funnel* - with the spout fitting into spray tube.

3.12 *Measure of Water* - having the necessary capacity to fill the indicator with water from the top of the concrete to the zero mark.

4 Calibration of Apparatus:

4.1 Calibration of the apparatus must be performed at the job site before air content determinations are made. The check cylinder and air meter must have the same number. Since the volumes of the air meters vary slightly, the meters must be individually calibrated and only their corresponding check cylinders may be used for this purpose. The calibration process is as follows:

4.1.1 Place the brass check cylinder in the dry air meter bowl with the open end down.

4.1.2. Fill the bowl with water and clamp on the top of the air meter.

4.1.3 Fill the assembled apparatus with water to the zero mark.

4.1.4 Close remaining valves and apply air pressure until the scale reading on the water glass gauge reads the same as the air content marked on the brass check cylinder.

4.1.5 Tap sides of the bowl and cover lightly with the mallet to remove any entrapped air and to relieve any local restraints.

4.1.6 Check the level of the water in the glass to see if it remains the same as the brass check cylinder and if so, record the air pressure.

4.1.7 Gradually release the air pressure by opening the funnel valve on top of the air meter cover and check if water level returns to the zero mark.

4.1.8 Repeat steps 4.1.4 through 4.1.7. If the water level returns to the same reading as before, record the psi on a piece of masking tape and place the tape on the air gauge glass.

4.1.9 If the water level fails to return within 0.05 percent of the zero mark, a check should be made to determine where leakage has occurred.

4.1.10 After leakage has been corrected, the entire calibration must be repeated.

5 Determination of Aggregate Correction Factor:

5.1 *Procedure* – Determine the aggregate correction factor on a combined sample of fine and coarse aggregate as directed in sections 6.2 to 6.4. It is determined independently by applying the calibrated pressure to a sample of inundated fine and coarse aggregate in approximately the same moisture condition, amount, and proportions occurring in the concrete sample under test.

5.2 *Aggregate Sample Size* – Calculate the weights of fine and coarse aggregate present in the sample of fresh concrete whose air content is to be determined, as follows:

$F_s = (S/B) \times F_b$

$C_s = (S/B) \times C_b$

where:

F_s = weight of fine aggregate in concrete sample under test, lb (kg);

5 Determination of Aggregate Correction Factor: (continued)

S = volume of concrete sample (same as volume of measuring bowl), ft^3 (m^3);

B = volume of concrete produced per batch (Note 2), ft^3 (m^3);

F_b = total weight of fine aggregate in the moisture condition used in batch, lb (kg);

C_s = weight of coarse aggregate in concrete sample under test, lb (kg), and

C_b = total weight of coarse aggregate in the moisture condition used in batch, lb (kg).

Note 2 – The volume of concrete produced per batch can be determined in accordance with applicable portions of T 121.

Note 3 – The term "weight" is temporarily used in this standard because of established trade usage. The word is used to mean both "force" and "mass" and care must be taken to determine which is meant in each case (SI unit for force = Newton and for mass = kilogram).

5.3 *Placement of Aggregate in Measuring Bowl* – Mix representative samples of fine aggregate F_s, and coarse aggregate C_s, and place in the measuring bowl filled one-third full with water. Place the mixed aggregate, a small amount at a time, into the measuring bowl; if necessary, add additional water so as to inundate all of the aggregate. Add each scoopful in a manner that will entrap as little air as possible and remove accumulations of foam promptly. Tap the sides of the bowl and lightly rod the upper 1 in. (25 mm) of the aggregate about 8 – 12 times. Stir after each addition of aggregate to eliminate entrapped air.

5.4 *Aggregate Correction Factor Determination:*

5.4.1 *Initial procedure for Types A and B Meters* – When all of the aggregate has been placed in the measuring bowl, remove excess foam and keep the aggregate inundated for a period of time approximately equal to the time between introduction of the water into the mixer and the time of performing the test for air content before proceeding with the determination as directed in section 5.4.2 and 5.4.3.

5.4.2 *Type A Meter* – Complete the test as described in Sections 7.2.1 and Note 1. The aggregate correction factor, G, is equal to $h_1 - h_2$. (See Figure 1)(Note 4)

5.4.3 *Type B Meter* – Perform the procedures as described in section 7.3.1. Remove a volume of water from the assembled and filled apparatus approximately equivalent to the volume of air that would be contained in a typical concrete sample of a size equal to the volume of the bowl. Complete the test as described in Section 7.3.2. The aggregate correction factor, G, is equal to the reading on the air-content scale minus the volume of water removed from the bowl expressed as a percent of the volume of the bowl. (See Figure 1)

Note 4 – The aggregate correction factor will vary with different aggregates. It can be determined only by test, since apparently it is not directly related to absorption of the particles. The test can be easily made and must not be ignored. Ordinarily the factor will remain reasonably constant for given aggregates, but an occasional check test is recommended.

6 Preparation of Concrete Test Sample:

6.1 Obtain the sample of freshly mixed concrete in accordance with applicable procedures of Method MT-105.

7 Procedure for Determining Air Content of Concrete:

7.1 Placement and Consolidation of Sample:

7.1.1 Dampen the interior of the measuring bowl and place it on a flat, level, firm surface. Place a representative sample of the concrete, prepared as described in section 5, in the measuring bowl in equal layers. Consolidate each layer by the rodding procedure (6.1.2). Strike off the final consolidated layer (6.1.3).

7.1.2 *Rodding* - Place the concrete in the measuring bowl in three layers of approximately equal volume. Consolidate each layer of concrete by 25 strokes of the tamping rod evenly distributed over the cross section. After each layer is rodded, tap the sides of the measure smartly 10 to 15 times with the mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. Rod the bottom layer throughout its depth, but the rod shall not forcibly strike the bottom of the measure. In rodding the second and final layers, use only enough force to cause the rod to penetrate the surface of the previous layer about 1 in. (25 mm). Add the final layer of concrete in a manner to avoid excessive overfilling (7.1.3).

7.1.3 *Strike-Off* - After consolidation of the concrete, strike off the top surface by sliding the strike-off bar across the top flange or rim of the measuring bowl with a sawing motion until the bowl is just level full. On completion of consolidation, the bowl must not contain a great excess or deficiency of concrete. Removal of approximately 1/8 in. (3 mm) during strike off is optimum. A small quantity of representative concrete may be added to correct a deficiency. If the measure contains a great excess, remove a representative portion of concrete with a trowel or scoop before the measure is struck off.

7.2 Procedure - Type A Meter:

7.2.1 *Preparation for Test* - Thoroughly clean the flanges or rims of the bowl and of the cover assembly so that when the cover is clamped in place a pressure-tight seal will be obtained. Assemble the apparatus and add water over the concrete by means of the tube until it rises about the halfway mark in the standpipe. Incline the apparatus assembly about 30 degrees from vertical and, using the bottom of the bowl as a pivot, describe several complete circles with the upper end of the column, simultaneously tapping the cover lightly to remove any entrapped air bubbles above the concrete sample. Return the apparatus assembly to a vertical position and fill the water column slightly above the zero mark, while lightly tapping the sides of the bowl. Bring the water level to the zero mark of the graduated tube before closing the vent at the top of the water column.

Note 1 - The internal surface of the cover assembly should be kept clean and free from oil or grease; the surface should be wet to prevent adherence of air bubbles that might be difficult to dislodge after assembly of the apparatus.

7.2.2 *Test Procedure* - Apply slightly more than the desired test pressure, P, (about 0.2 psi) (1,380 Pa more, as described in 4.1.4) to the concrete by means of the small hand pump. To relieve local restraints, tap the sides of the measure sharply and, when the pressure gage indicates the exact test pressure, as described in 4.1.6, read the water level, h_1, and record to the nearest division or half-division on the graduated precision-bore tube or gage glass of the standpipe. The value is the percentage of air in the concrete. For extremely harsh mixes it may be necessary to tap the bowl vigorously until further tapping produces no change in the indicated air content. Gradually release the air pressure through the vent at the top of the water column and tap the sides of the bowl lightly for about one min. Record the water level, h_2, to the nearest division or half division. Calculate the apparent air content as follows:

$$A_1 = h_1 - h_2$$

7.2 Procedure - Type A Meter: (continued)

where:

A_1 = apparent air content.

h_1 = water level reading at pressure, P.

h_2 = water level reading at zero pressure after release of Pressure, P.

7.2.3 *Check Test* - Repeat the steps described in 7.2.2 without adding water to reestablish the water level at the zero mark. The two consecutive determinations of apparent air content should check within 0.2% of air and shall be averaged to give the value of air in the concrete as a percentage.

7.3 Procedure - Type B Meter:

7.3.1 *Preparation for Test* - Thoroughly clean the flanges or rims of the bowl and the cover assembly so that when the cover is clamped in place a pressure tight seal will be obtained. Assemble the apparatus. Close the air valve between the air chamber and measuring bowl and open both petcocks on the holes through the cover. Using a rubber syringe, inject water through one petcock until water emerges from the opposite petcock. Jar the meter gently until all air is expelled from the same petcock.

7.3.2 *Test Procedure* - Close the air bleeder valve on the chamber and pump air into the air chamber until the gage hand is on the initial pressure line. Allow a few seconds for the compressed air to cool to normal temperature. Stabilize the gage hand at the initial pressure line by pumping or bleeding-off air as necessary, tapping the gage lightly by hand. Close both petcocks on the holes through the cover. Open the air valve between the air chamber and the measuring bowl. Tap the side of the measuring bowl smartly with the mallet to relieve local restraints. Lightly tap the pressure gage by hand to stabilize the gage hand and read the percentage of air on the dial of the pressure gage. Failure to close the main valve before releasing the pressure from either the container or the air chamber will result in water being drawn into the air chamber, thus introducing error in subsequent measurements. In the event water enters the air chamber, it must be bled from the air chamber through the bleeder valve followed by strokes of the pump to blow out the last traces of water. Release the pressure by opening both petcocks before removing the cover.

8 Calculation:

8.1 *Air Content of Sample Tested* – Calculate the air content of the concrete in the measuring bowl as follows:

$A_s = A_1 - G$

where:

As = air content of sample tested, percent;

A1 = apparent air content of the sample tested, percent (Section 7.2.2 and 7.2.3); and

G = aggregate correction factor, percent (Section 5).

9 Simple Maintenance:

9.1 Air meters must be kept clean to give accurate readings.

9.1.1 Thoroughly clean and dry equipment after each use. Never clamp and store meter while bowl is still damp.

9 Simple Maintenance: (continued)

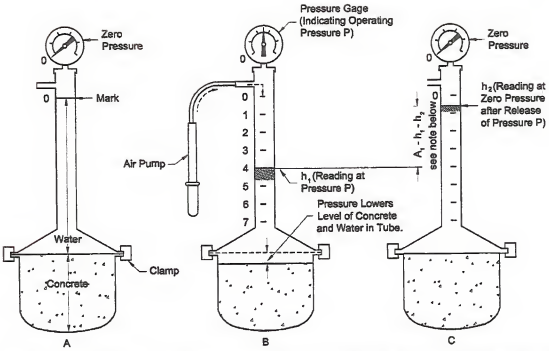
9.1.2 Occasionally clean and oil threads in the funnel valve. It is extremely important that threads on the hold down clamps be cleaned and oiled at all times.

9.1.3 Never strike the surface of the bowl where the gasket rests.

9.1.4 Occasionally oil the petcocks and clean openings with a fine wire.

9.1.5 Clean the water glass occasionally. This can be done by removing the valve from the funnel and using the brush, which is included for that purpose.

9.1.6 To prevent sticking and destroying the rubber gasket, a piece of waxed paper should be placed between the bowl and cover when the apparatus is stored.



Notes: $A_1 = h_1 - h_2$ when bowl contains concrete as shown in this figure; when bowl contains only aggregate and water, $h_1 - h_2 = G$ (aggregate correction factor.)
$A_1 - G = A$ (entrained air content of concrete).

Figure 1—Illustration of the Pressure Method for Air Content—Type A Meter

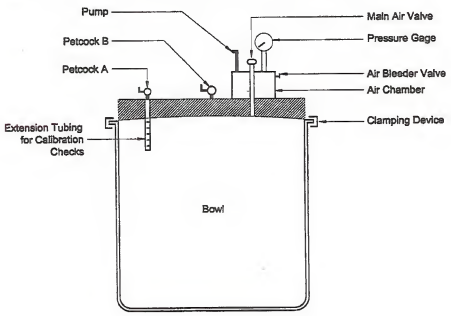


Figure 2—Schematic Diagram—Type B Meter

METHODS OF SAMPLING AND TESTING
MT 104-04
METHOD OF TEST FOR
SLUMP OF PORTLAND CEMENT CONCRETE
(Modified AASHTO T 119)

1 Scope:

1.1 This test method covers determination of slump of concrete, both in the laboratory and in the field (Note 1).

Note 1 - This test is not considered applicable to non-plastic and non-cohesive concrete, nor when there is a considerable amount of coarse aggregate over two inches (50 mm) in size in concrete.

1.2 This standard may involve hazardous materials, operations and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Referenced Documents:

2.1 ***MT Materials Manual:***
MT105 Sampling Fresh Concrete

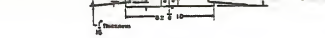
3 Summary of Test Method:

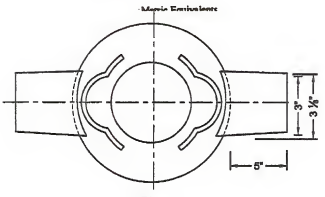
3.1 A sample of freshly mixed concrete is placed and compacted by rodding in a mold shaped as the frustum of a cone. The mold is raised, and the concrete allowed to subside. The distance between the original and displaced position of the center of the top surface of the concrete is measured and reported as the slump of the concrete.

4 Apparatus:

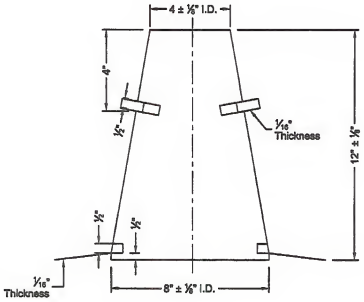
4.1 *Mold* - The test specimen shall be formed in a mold made of metal not readily attacked by the cement paste. The metal shall not be thinner than No. 16 gage (BWG) and if formed by the spinning process, there shall be no point on the mold at which the thickness is less than 0.045 in. (1.14 mm). The mold shall be in the form of the lateral surface of the frustum of a cone with the base 8 in. (203 mm) in diameter, the top 4 in. (102 mm) in diameter, and the height 12 in. (305 mm). Individual diameters and heights shall be within ± 1/8 in. (3.2 mm) of the prescribed dimensions. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mold shall be provided with foot pieces and handles similar to those shown in Figure 1. The mold may be constructed either with or without a seam. When a seam is required, it should be essentially as shown in Fig. 1. The interior of the mold shall be relatively smooth and free from projections such as protruding rivets. The mold shall be free from dents. A mold which clamps to a nonabsorbent base plate is acceptable instead of the one illustrated provided the clamping arrangement is such that it can be fully released without movement of the mold.

4.2 *Tamping Rod* - The tamping rod shall be a round, straight steel rod 5/8 in. (16 mm) in diameter and approximately 24 in. (600 mm) in length, having the tamping end rounded to a hemispherical tip the diameter of which is 5/8 in. (16 mm).





Plan



Dimensional Units

mm	1.6	3.2	12.7	25.4	38.1	76.2	79.4	102	203	305
in.	1/16	1/8	1/2	1	1 1/2	3	3 1/8	4	8	12

Note: All dimensions shown in millimeters unless otherwise noted.

5 Sampling:

5.1 The sample of concrete from which test specimens are made shall be representative of the entire batch. It shall be obtained in accordance with MT 105.

6 Procedure:

6.1 Dampen the mold and place it on a flat, moist, nonabsorbent (rigid) surface. It shall be held firmly in place during filling by the operator standing on the two foot pieces. From the sample of concrete obtained in accordance with Section 5, immediately fill the mold in three layers, each approximately one third the volume of the mold (Note 2).

Note 2 - One third of the volume of the slump mold fills it to a depth of 2 5/8 in. (67 mm); two thirds of the volume fills it to a depth of 6 1/8 in. (155 mm).

6 Procedure: (continued)

6.2 Rod each layer with 25 strokes of the tamping rod. Uniformly distribute the strokes over the cross section of each layer. For the bottom layer this will necessitate inclining the rod slightly and making approximately half of the strokes near the perimeter, and then progressing with vertical strokes spirally toward the center. Rod the bottom layer throughout its depth. Rod the second layer and the top layer each throughout its depth, so that the strokes just penetrate into the underlying layer.

6.3 In filling and rodding the top layer, heap the concrete above the mold before the rodding is started. If the rodding operation results in subsidence of the concrete below the top edge of the mold, add additional concrete to keep an excess of concrete above the top of the mold at all times. After the top layer has been rodded, strike off the surface of the concrete by means of a screening and rolling motion of the tamping rod. Remove the mold immediately from the concrete by raising it carefully in a vertical direction. Raise the mold a distance of 12 in. (300 mm) in 5 ± 2 seconds by a steady upward lift with no lateral or torsional motion. Complete the entire test from the start of the filling through the removal of the mold without interruption and complete it within an elapsed time of 2 ½ min.

6.4 Immediately measure the slump by determining the vertical difference between the top of the mold and the displaced original center of the top surface of the specimen. If a decided falling away or shearing off of concrete from one side or portion of the mass occurs (Note 3), disregard the test and make a new test on another portion of the sample.

Note 3 - If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of the concrete from the mass of the specimen, the concrete probably lacks necessary plasticity and cohesiveness for the slump test to be applicable.

7 Report

7.1 Record the slump in terms of inches (millimeters) to the nearest 1/4 in. (6 mm) of subsidence of the specimen during the test as follows:

Slump = 12 - inches of height after subsidence

METHODS OF SAMPLING AND TESTING
MT 105-04
METHOD OF SAMPLING FRESH CONCRETE
(Modified AASHTO T 141)

1 Scope:

1.1 This method describes the procedures for obtaining representative samples of fresh concrete as delivered to the project site and on which tests are to be performed to determine compliance with quality requirements of the specifications under which the concrete is furnished (Note 1). The method includes sampling from stationary, paving and truck mixers, and from agitating and non-agitating equipment used to transport central mixed concrete.

Note 1 - Composite samples are required by this method, unless specifically excepted by procedures governing the tests to be performed such as tests to determine uniformity of consistency and mixer efficiency. Procedures used to select the specific test batches are not described in this method, but it is recommended that random sampling be used to determine overall specification compliance.

1.2 This method also covers the procedures to be used for preparing a sample of concrete for further testing where it is desirable or necessary to remove the aggregate larger than a designated size. This removal of larger aggregate particles is preferably accomplished by wet-sieving. (See paragraph 5.4.)

2 Referenced Documents:

2.1 ***AASHTO Standards:***
T 119 Slump of Portland Cement Concrete
T 121 Weight Per Cubic Foot, Yield, and Air Content (Gravimetric) of Concrete

MT Manual:
MT-405 Wire Cloth Sieves for Testing Purposes

3 Sampling:

3.1 The elapsed time between obtaining the first and final portions of the composite samples shall be as short as possible, but in no instance shall it exceed 15 min.

3.1.1 Transport the individual samples to the place where fresh concrete tests are to be performed or where test specimens are to be molded. They shall then be combined and remixed with a shovel the minimum amount necessary to ensure uniformity and compliance with the minimum time limits specified in Section 3.1.2.

3.1.2 Start tests for slump or air content, or both, within 5 min. after obtaining the final portion of the composite sample. Complete these tests as expeditiously as possible. Start molding specimens for strength tests within 15 min. after fabricating the composite sample. Keep the elapsed time between obtaining and using the sample as short as possible and protect the sample from the sun, wind, and other sources of rapid evaporation, and from contamination.

4 Procedure:

4.1 *Size of Sample*--Make the samples to be used for strength tests a minimum of 1 ft^3 (28 liters). Smaller samples may be permitted for routine air content and slump tests and the size shall be dictated by the maximum aggregate size.

4 **Procedure:** (continued)

4.2 The procedures used in sampling shall include the use of every precaution that will assist in obtaining samples that are truly representative of the nature and condition of concrete sampled as follows:

Note 2 - Sampling should normally be performed as the concrete is delivered from the mixer to the conveying vehicle used to transport the concrete to the forms; however, specifications may require other points of sampling, such as at the discharge of a concrete pump.

Note 3 - As routine air content and slump tests are not readily adaptable to sampling the concrete at two or more regularly spaced intervals during discharge of the middle portion of the batch as specified in this method, the sample for air content, slump, and temperature may be taken after at least one-quarter cubic yard of concrete has been discharged.

4.2.1 *Sampling from Stationary Mixers, Except Paving Mixers*--Sample the concrete at two or more regularly spaced intervals during discharge of middle portion of the batch. Take the samples within the time limit specified in Section 3, and composite them into one sample for test purposes. Do not obtain samples from the very first or last portions of the batch discharge. Perform sampling by passing a receptacle completely through the discharge stream, or by completely diverting the discharge into a sample container. If discharge of the concrete is too rapid to divert the complete discharge stream, discharge the concrete into a container or transportation unit sufficiently large to accommodate the entire batch and then accomplish the sampling in the same manner as given above. Take care not to restrict the flow of concrete from the mixer, container, or transportation unit so as to cause segregation. These requirements apply to both tilting and non-tilting mixers.

4.2.2 *Sampling from Paving Mixers*--Sample the concrete after the contents or the paving mixer have been discharged. Obtain samples from at least five different portions of the pile and then composite into one sample for test purposes. Avoid contamination with subgrade material or prolonged contact with an absorptive subgrade. To preclude contamination or absorption by the subgrade, sample the concrete by placing three shallow containers on the subgrade and discharging the concrete across the containers. Composite the samples so obtained into one sample for tests purposes. the containers shall be of a size sufficient to provide a composite sample size that is in agreement with the maximum aggregate size.

Note 4 - In some instances, the containers may have to be supported above the subgrade to prevent displacement during discharge.

4.2.3 *Sampling from Revolving Drum Truck Mixers or Agitators*--Sample the concrete at two or more regularly spaced intervals during discharge of the middle portion of the batch. Take the samples within the time limit specified in Section 3 and composite them into one sample for test purposes. In any case do not obtain samples until after all of the water has been added to the mixer; also do not obtain samples from the very first or last portions of the batch discharge. Sample by repeatedly passing a receptacle through the entire discharge stream or by completely diverting the discharge into a sample container. Regulate the rate of discharge of the batch by the rate of revolution of the drum and not by the size of the gate opening.

4.2.4 *Sampling from Open-Top Truck Mixers, Agitators, Non-agitating equipment, or Other Types of Open-Top Containers*--Take samples by whichever of the procedures described in 4.2.1. 4.2.2, or 4.2.3 is most applicable under the given conditions

5 Additional Procedure for Large Maximum Size Aggregate Concrete:

5.1 When the concrete contains aggregate larger than that appropriate for the size of the molds or equipment to be used, wet-sieve the sample as described below except make unit-weight tests for use in yield computations on the full mix.

5 Additional Procedure for Large Maximum Size Aggregate Concrete: (continued)

Note 5 - The effect of wet-sieving the test results should be considered. For example, wet-sieving concrete causes the loss of a small amount of air due to additional handling. The air content of the wet-sieved fraction of concrete is greater than that of the total concrete because the larger size aggregate, which is removed, does not contain air. The apparent strength of wet-sieved concrete in smaller specimens is usually greater than that of the total concrete in larger appropriate size specimens. The effect of these differences may need to be considered or determined by supplementary testing for quality control or test result evaluation purposes.

5.2 Definition:

5.2.1 *Wet-Sieving Concrete* - The process of removing aggregate larger than a designated size from the fresh concrete by sieving it on a sieve of the designated size.

5.3 Apparatus:

5.3.1 *Sieves* - as designated, conforming to MT-405, Wire-Cloth Sieves for Testing Purposes.

5.3.2 *Wet-Sieving Equipment* - Equipment for wet-sieving concrete shall be a sieve as noted in 5.3.1 of suitable size and conveniently arranged and supported so that one can shake it rapidly by either hand or mechanical means. Generally, a horizontal back and forth motion is preferred. The equipment shall be capable of rapidly and effectively removing the designated size of aggregate.

5.3.3 *Hand Tools* - Shovels, hand scoops, plastering trowels, and rubber gloves as required.

5.4 Procedure:

5.4.1 *Wet-Sieving* - After sampling the concrete, pass the concrete over the designated sieve and remove and discard the aggregate retained. This shall be done before remixing. Shake or vibrate the sieve by hand or mechanical means until no undersize material remains on the sieve. Mortar adhering to the aggregate retained on the sieve shall not be wiped from it before it is discarded. Place only enough concrete on the sieve at any one time so that after sieving, the thickness of the layer of retained aggregate is not more than one particle thick. The concrete which passes the sieve shall fall into a batch pan of suitable size which has been dampened before use or onto a clean, moist, nonabsorbent surface. Scrape any mortar adhering to the sides of the wet-sieving equipment into the batch. After removing the larger aggregate particles by wet-sieving, remix the batch with a shovel the minimum amount necessary to ensure uniformity and proceed testing immediately.

METHODS OF SAMPLING AND TESTING
MT 106-04
METHOD OF MEASURING LENGTH OF DRILLED CONCRETE CORES
(Modified AASHTO T 148)

1 Scope:

1.1 This method covers the procedure for determining the length of a core drilled from a concrete pavement or structure.

2 Referenced Documents:

2.1 ***AASHTO:***
T 148 Measuring Length of Drilled Concrete Cores

2 Apparatus:

2.1 The apparatus shall consist of a caliper that will measure the length of axial elements of the core. While the details of the mechanical design are not prescribed, the apparatus shall conform to the requirements of paragraphs 2.2 through 2.6, inclusive.

2.2 The apparatus shall be so designed that the specimen will be held with its axis in a vertical position by three symmetrically placed supports bearing against the lower end. These supports shall be short posts or studs of hardened steel, and the ends that bear against the surface of the specimen shall be rounded to a radius of not less than 6.4 mm (¼ inch) and not more than 12.7 mm (½ inch).

2.3 The apparatus shall provide for the accommodation of specimens of different nominal lengths over a range of at least 100 to 250 mm (4 to 10 inches).

2.4 The caliper shall be so designed that it will be possible to make a length measurement at the center of the upper end of the specimen and at eight additional points. The additional points should be spaced at equal intervals along the circumference of a circle whose center point coincides with that of the end area of the specimen and whose radius is not less than one-half nor more than three-fourths of the radius of the specimen.

2.5 The measuring rod or other device that makes contact with the end surface of the specimen for measurement shall be rounded to a radius of 3.2 mm (1/8 inch). The scale on which the length readings are made shall be marked with clear, definite, and accurately spaced graduations. The spacing of the graduations shall be 2.54 mm (0.10 inch) or a decimal part thereof.

2.6 The apparatus shall be stable and sufficiently rigid to maintain its shape and alignment without a distortion or deflection of more than 0.25 mm (0.01 inch) during all normal measuring operations. (Note 1)

Note 1 - For further information relating to the development of this method and apparatus, reference should be made to the "Project Report on a Study of Methods of Measurement of the Length of Cores Drilled from Concrete Structures," prepared by L.W. Teller for Subcommittee VII on Methods and Apparatus for Testing Concrete, of Committee C-9, see *Proceedings, Am. Soc. for Testing Materials, Vol. 41 (1942).*

3 Test Specimen:

3.1 Cores used as specimens for length measurement shall be in every way representative of the concrete in the structure from which they are removed. The specimen shall be drilled with the axis normal to the surface of the structure, and the ends shall be free from all conditions not typical of the surfaces of the structure. Cores that show abnormal defects or that have been damaged appreciably in the drilling operation shall not be used.

4 Procedure:

4.1 Before any measurements of the core length are made, the apparatus shall be calibrated with suitable gages so that errors caused by mechanical imperfections in the apparatus are known. When these errors exceed 0.25 mm (0.01 inch), suitable corrections shall be applied to the core length measurements.

4.2 The specimen shall be placed in the measuring apparatus with the smooth end of the core (that is, the end that represents the upper surface of a pavement slab or a formed surface in the case of other structures) placed down so as to bear against the three hardened-steel supports. The specimen shall be so placed on the supports that the central measuring position of the measuring apparatus is directly over the mid-point of the upper end of the specimen.

4.3 Nine measurements of the length shall be made on each specimen, one at the central position and one each at eight additional positions spaced at equal intervals along the circumference of the circle of measurement described in paragraph 2.4. Each of these nine measurements shall be read directly to 2.5 mm (0.10 inch)) and to 1.27 mm (0.05 inch) either directly or by estimation. (Note 2)

Note 2 - If, in the course of the measuring operation it is discovered that at one or more of the measuring points the surface of the specimen is not representative of the general plane of the core end because of a small projection or depression, the specimen shall be rotated slightly about its axis and a complete set of nine measurements made with the specimen in the new position.

5 Report:

5.1 The individual observation shall be recorded to the nearest 1.27 mm (0.05 inch) and the average of the nine measurements expressed to the nearest 2.5 mm (0.10 inch) shall be reported as the length of the concrete core.

METHODS OF SAMPLING AND TESTING
MT 107-04
METHOD OF DETERMINING AIR CONTENT OF FRESHLY MIXED CONCRETE BY THE VOLUMETRIC METHOD
(Modified AASHTO T 196)

1 Scope:

1.1 This method covers determination of the air content of freshly mixed concrete containing any type of aggregate, whether it is dense, cellular, or light-weight.

2 Reference Documents:

2.1 ***AASHTO:***
T 196 Air Content of Freshly Mixed Concrete by the Volumetric Method

MT Materials Manual:
MT-102 Air Content of Freshly Mixed Concrete by the Pressure Method
MT-105 Sampling Fresh Concrete
MT-115 Unit Weight, Yield, and Air Content (Gravimetric) of Concrete
MT-203 Unit Weight of Aggregate

3 Apparatus:

3.1 *Airmeter* - An airmeter consisting of a bowl and a top section (Figure 1) conforming to the following requirements:

3.1.1 *Bowl* - The bowl shall be constructed of machined metal of such thickness as to be sufficiently rigid to withstand normal field use and of such composition as not to be readily attacked by cement paste. The bowl shall have a diameter equal to 1 to 1.25 times the height and be constructed with a flange at or near the top surface. Bowls shall not have a capacity of less than 0.075 $ft.^3$ (0.002m^3).

3.1.2 *Top Section* - The top section shall be constructed of machined metal of thickness sufficiently rigid to withstand normal field use and of composition not readily attacked by cement paste. The top section shall have a capacity at least 20 percent larger than the bowl and shall be equipped with a flexible gasket and with hooks or lugs to attach to the flange on the bowl to make a watertight connection. The top section shall be equipped with a glass-lined transparent plastic neck, graduated in increments not greater than 0.5 percent from 0 at the top to 9 percent, or more, of the volume of the bowl. Graduations shall be accurate to ± 0.1 percent by volume of the bowl. The upper end of the neck shall be threaded and equipped with a screw cap having a gasket to make a water-tight fit.

3.2 *Funnel* - A metal funnel with a spout of a size permitting it to be inserted through the neck of the top section and long enough to extend to a point just above the bottom of the top section. The discharge end of the spout shall be so constructed that when water is added to the container there will be a minimum disturbance of the concrete.

3.3 *Tamping Rod* - A round, straight steel rod, 0.625 in. or 16 mm in diameter at least 12 in. or 300 mm long with both ends rounded to a hemispherical tip of the same diameter.

3.4 *Strike-off Bar* - A flat, straight steel bar at least 1/4 by 3/4 by 12 in. or 3 by 20 by 300 mm long.

3.5 *Measuring Cup* - A metal cup having a capacity equal to 1.03 ± 0.04 percent of the volume of the bowl of the air meter.

3 Apparatus: (continued)

Note 1 - The volume of the measuring cup is slightly larger than 1.0 percent of the volume of the bowl to compensate for the volume contraction that takes place when 70 percent isopropyl alcohol is mixed with water. Other alcohols or defoaming agents may be used if calculations show that their use will result in an error indicated air content less than 0.1 percent.

3.6 *Syringe* - A small rubber bulb syringe having a capacity at least that of the measuring cup.

3.7 *Pouring Vessel* - A metal or glass container of approximately 1 qt. or 1 litre capacity.

3.8 *Trowel* - A blunt-nosed brick mason's trowel.

3.9 *Scoop* - A small metal scoop.

3.10 *Isopropyl Alcohol* - Use 70 percent by volume isopropyl alcohol (approximately 65 percent by weight) (Notes 1 and 2).

Note 2 - Seventy percent isopropyl alcohol is commonly available as rubbing alcohol. More concentrated grades can be diluted with water to the required concentration.

3.11 *Mallet* - A mallet (with a rubber or rawhide head) weighing approximately 1.25 ± 0.50 lb. (0.57 ± 0.23 kg) for use with measures of 0.5 ft³ (0.014 m³) or smaller, and a mallet weighing approximately 2.25 ± 0.50 lb. (1.02 ± 0.23 kg) for use with measures larger than 0.5 ft³ (0.014 m³).

4 Calibration of Apparatus:

4.1 The volume of the bowl of the air-meter in cubic feet or cubic metres shall be determined by accurately weighing the amount of water required to fill it at room temperature, and dividing this weight by the unit weight of water at the same temperature. Follow the calibration procedure outlined in Section 6 of Method MT-203.

4.2 Determine the accuracy of the graduations on the neck of the top section of the air meter by filling the assembled measuring bowl and top section with water to a preselected air content graduation and then determining the quantity of 70° F (21.1°C) water required to fill the meter to the zero mark. The quantity of water added shall equal the preselected air content graduation within ± 0.1 volume percent of the measuring bowl. Repeat the procedure to check a minimum of 3 graduations within the expected range of use.

4.3 Determine the volume of the measuring cup using water at 70° F (21.1° C) by the method outlined in Section 6.1. A quick check can be made by adding one or more cups of water to the assembled apparatus and observing the increase in the height of the water column after filling to a given level as described in Section 6.2.

5 Sample:

5.1 Obtain the sample of freshly mixed concrete in accordance with applicable provisions of Method MT-105. If the concrete contains coarse aggregate particles that would be retained on a ½ in. (37.5 mm) sieve, wet sieve a representative sample over a 1 in. (25 mm) sieve to yield somewhat more than enough material to fill the measuring bowl. The wet sieving procedure is described in Method MT-105. Carry out the wet sieving operation with the minimum practicable disturbances of the mortar. Make no attempt to wipe adhering mortar from coarse aggregate particles retained on the sieve.

6 **Procedure:**

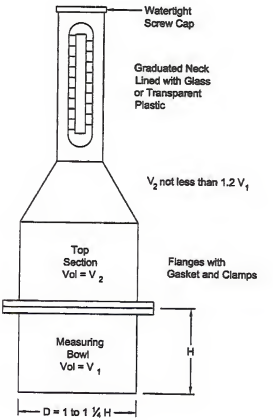
6.1 *Rodding and Tapping* - Using the scoop, aided by the trowel if necessary, fill the bowl with freshly mixed concrete in three layers of equal depth. Rod each layer 25 times with the tamping rod. After each layer is rodded, tap the sides of the measure 10 to 15 times smartly with the mallet to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped.

6.2 *Striking Off* - After placement of the third layer of concrete in accordance with Section 6.1, strike off the excess concrete with the strike-off bar until the surface is flush with the top of the bowl. Wipe the flange of the bowl clean.

6.3 *Adding Water* - Clamp the top section into position on the bowl, insert the funnel, and add water until it appears in the neck. Remove the funnel and adjust the water level, using the rubber syringe until the bottom of the meniscus is level with the zero mark. Attach and tighten the screw cap.

6.4 *Agitating and Rolling* - Invert and agitate the unit until the concrete settles free from the base; and then, with the neck elevated, roll and rock the unit until the air appears to have been removed from the concrete. Set the apparatus upright, jar it lightly and allow it to stand until the air rises to the top. Repeat the operation until no further drop in the water column is observed.

6.5 *Dispelling Bubbles* - When all the air has been removed from the concrete and allowed to rise to the top of the apparatus, remove the screw cap. Add, in one cup increments, using the syringe, sufficient isopropyl alcohol to dispel the foamy mass on the surface of the water.



6 P

Figure 1—Apparatus for Measuring Air Content of Fresh Concrete by Volumetric Method

6 Procedure: (continued)

6.6 *Reading* - Make a direct reading of the liquid in the neck, reading to the bottom of the meniscus, and estimating to the nearest 0.1 percent.

7 Calculation:

7.1 Calculate the air content percent of the concrete in the measuring bowl in percent by adding to the reading from Section 6.6 the amount of alcohol used in accordance with Section 6.5.

7.2 When the sample tested represents that portion of the mixture obtained by wet sieving over a 1 in. (25 mm) sieve, calculate the air content of the mortar or of the full mixture using the formulas given in Method MT-102. Use appropriate quantities coarser or finer than the 1 in. (25 mm) sieve instead of the 1½ in. (37.5 mm) sieve specified in Method MT-102.

METHODS OF SAMPLING AND TESTING
MT 108-04
SAMPLING AND CERTIFICATION OF PORTLAND CEMENT

1 Scope:

1.1 This method covers the requirements for sampling and certification of portland cement.

2 General:

2.1 Cement samples shall weigh a minimum of 6.8 Kg (15 pounds). Such samples shall be placed in air-tight plastic bags which shall in turn be placed in canvas bags to protect against breakage during shipment. The bin or silo number and the grind number shall be shown on the Lab. Form No. 55 to accompany the sample.

3 Procedure:

3.1 A sample of cement shall be submitted to the Materials Bureau, prior to construction, for all projects which involve bridge construction or projects which involve 114.3 cubic meters (125 cubic yards) of concrete. The sample may be taken from existing stock at the ready mix plant. On many projects this will be the only sample required unless the provisions of paragraph 4 make additional sampling necessary.

4 Sampling Frequency:

4.1 *Project Sampling*

4.1.1 *Bridge Projects:*

4.1.1.1 Minimum of one sample taken prior to the start of concrete production.

4.1.1.2 One sample for each additional 458.6 cubic meters (600 cubic yards) of concrete used.

4.1.1.3 This procedure shall be used regardless of the number of structures involved in the project.

4.2 *Paving Projects:*

4.2.1 One sample taken prior to the start of concrete production.

4.2.2 Additional samples taken for each 4572.0 cubic meters (5,000 cubic yards) of concrete produced.

4.3 *Cement Treated Base Projects:*

4.3.1 One sample taken at the start of the project.

4.4 *Miscellaneous Projects (cattle guards, sign bases, etc.):*

4.4.1 One sample taken prior to the start of concrete production on jobs involving 114.3 cubic meters (125 cubic yards) of concrete or more.

4.4.2 Samples need not be submitted for projects involving less than 114.3 cubic meters (125 cubic yards) of concrete.

4.5 Random Sampling:

4.5.1 Each district shall, in addition to samples taken in accordance with paragraph 4.1 above, submit a random sample of each brand of cement used in that district during the year. These samples may be taken at any time during the year.

5 Cement Certification:

5.1 The cement plants shall furnish the Materials Bureau with certified test results for each new grind or bin of cement produced for use within the state.

5.2 Each shipment of cement from the manufacturing plant to a highway project shall be accompanied by a certificate of compliance. This certificate shall state that the cement complies with all the requirements of AASHTO M-85 or ASTM C-150, low alkali cement, and shall be signed by a responsible representative of the cement plant. Two copies of this certification shall accompany the shipment, one for the consignee and one for the Engineering Project Manager.

METHODS OF SAMPLING AND TESTING
MT 109-04
METHOD OF SAMPLING WATER

1 Scope:

1.1 This method covers the sampling of water for determination of its suitability for use in concrete, for determination of corrosivity, and for chemical testing for potability. It does not include sampling for biological testing.

2 Application:

2.1 This method is applicable to sampling industrial and domestic water supplies from sources such as wells, rivers, streams, lakes, ponds, reservoirs, pipelines and conduits for chemical or physical tests.

3 Point of Sampling:

3.1 Where the water in a stream is mixed so as to approach uniformity, a sample taken at any point in the cross section is satisfactory.

3.2 For bodies of water such as ponds or reservoirs, avoid surface and/or bottom sampling and attempt to obtain an integrated sample containing water from all points in a vertical section. Depending upon the nature of the source being sampled, it may be desirable to sample at several points and to combine the samples to obtain a representative sample of the source.

3.3 In sampling from pipelines, conduits, pump discharge, etc., make certain that all conduits have been flushed. In the case of water wells, initial pumping for well cleaning purposes shall have been completed so the sample represents the sustained output of the source.

4 Frequency of Sampling:

4.1 A sample of the water proposed for use shall be submitted in accordance with the frequency specified in MT-601.

5 Volume of Sample and Type of Container:

5.1 Furnish a one liter (quart) sample in a clean glass or plastic bottle or jar with a screw cap lid with liner. Fill almost to the top, but allow a small space to allow for possible expansion due to temperature change.

6 Labeling:

6.1 Label with identifying source data and state the purpose for which the sample is taken.

METHODS OF SAMPLING AND TESTING
MT 110-04
METHOD OF TEST FOR
REINFORCED CONCRETE PIPE AND ASSOCIATED ITEMS
(Montana Test Method)

1 Scope:

1.1 The testing of concrete pipe and associated items will be done by the District laboratories where concrete plants are located. The Helena plant of the Elk River Company will be handled by the Materials Bureau. A jack, a wire gage, a supply of the necessary blank forms and a manual of instructions has been supplied to the District concerned.

2 Referenced Documents:

2.1 ***MT Manual:***
MT-108 Sampling and Certification of Portland Cement

3 Materials:

3.1 The materials covered by this procedure are those used in manufacturing reinforced concrete pipe, drop inlets, station markers, R/W monuments, guardrail posts and other pre-cast concrete items.

3.1.1 *Aggregates* - Samples of the aggregate used will be submitted to the Materials Bureau once a year, or whenever the source of supply changes. Acceptable reports showing NC laboratory numbers will be returned to the field for the District files and use on Form No. 19A.

3.1.2 *Cement* - Cement will be accepted by certificate in conformance with MT-108, Sampling and Certification of Portland Cement, except that the certificate which accompanies the shipment of cement shall be kept at the plant where the material is being fabricated. The certificate will be picked up by the District laboratory personnel who are charged with the responsibility for making the inspection of Reinforced Concrete Pipe and Associated Items and kept on file in the District laboratory.

3.1.3 *Reinforcing Steel and Wire Mesh* - It will be the responsibility of the pipe companies to notify the District laboratories when shipments of steel are received. Samples will then be sent to the Materials Bureau. Reports of acceptability will be returned to the District laboratory for their files and use on Form No. 19A.

3.1.4 *Concrete Cylinders* - Concrete cylinders, in sets of three, will be made periodically to represent the concrete placed in all concrete items. These cylinders need not be made for each project but a set should be made at such times as to fully represent the concrete being produced. These cylinders will be sent to the Materials Bureau showing the plant name and location as the project number. The cylinders will be assigned NC laboratory numbers in the Materials Bureau and when the cylinder reports are received back in the field, these NC numbers will be recorded on Form No. 19 to represent all concrete items not actually tested, and they shall be kept on file in the District laboratory.

3.1.5 *Pipe Strength Tests* - Actual strength tests will be made periodically in accordance with Montana Standard Specifications on concrete pipe within the range of the jack. These tests will be made whenever the need arises and they shall be reported on Laboratory Form No. 19. A copy of this report shall be sent to the Materials Bureau immediately for the assigning of NC Laboratory Numbers, after which it will be returned to the District laboratory for the District files. Laboratory Form No. 19 is self-explanatory as far as pipe entries are concerned. The column marked "absorption" may be ignored when conducting routine strength tests. Absorptions are run on sections of pipe representing a cross section of all of the concrete produced by the plant twice a year, usually in the spring and the fall.

3 Materials: (continued)

Sometime when routine pipe testing is being done, in the spring or again in the fall, the pipe being tested will be destroyed and absorption specimens obtained in accordance with Montana Standard Specifications. These absorption specimens will be sent to the Materials Bureau for testing and when the results are sent back to the District laboratory, they will be recorded on Form 19 covering the sections of pipe from which the samples were taken.

3.1.6 *Concrete items other than concrete pipe* - will also be entered on Form No. 19. These items, together with pipe too large to test, are represented by cylinder tests outlined above.

4 Procedure:

4.1 The procedure for listing concrete items used on the job and which require testing or certification is listed below.

4.1.1 Four copies are to be sent to the District where the project is located with one copy for the District Engineer, one copy for the Field Project Manager, one copy for the District Materials Supervisor and one copy to the Materials Bureau in Helena. One additional copy is to be sent to the Area Lab Supervisor if applicable. The District performing the inspection shall retain a copy for their records.

4.1.2 Lab. Form 19A - Concrete Items Certificate - When a significant portion of the concrete items have been tested and approved and are shipped to the project, this form shall be completed by the inspector and copies forwarded as follows:

4.1.1.1 Four copies are to be sent to the Supervisor, Division Construction Section, where the project is located with one copy to be marked for the attention of the Project Manager in charge of the project, one copy to the division office where the concrete items are being manufactured, and one copy to the Materials Bureau at Helena.

4.1.1.2 Three or more certificates may be required during the course of the project - one covering pipe items, another covering drop inlets, etc., and one covering station markers and guardrail posts.

5 Mark of Acceptance:

5.1 All concrete pipe must carry a mark of acceptance. The mark that has been adopted is a circle approximately 1 3/4 inches (44mm) in diameter with a black capitalM in the center (see Fig. 1). This will be stamped on each length of pipe where it will be clearly visible. Absence of a Circle M Stamp will indicate a pipe is not complete, requires corrective work, or that the inspector was not present at the time the pipe was loaded on the truck for shipment.

5.1.1 This procedure does not make any change in our policy of accepting all pipe at the point of delivery. The circleM merely indicates the pipe was acceptable in the manufacturer's yard at the time it was inspected. Final acceptance must be made in the field and field personnel should be instructed to reject any concrete pipe which, in their opinion, is not acceptable after delivery to the job site.

6 Notification by Manufacturers:

6.1 The manufacturers of concrete pipe and other concrete items are hereby requested to notify the Highway Inspector before any shipments are made so that it is certain that all items to be shipped have been tested, inspected and properly marked. They are also warned that any shipments made without proper clearance and markings will be rejected in the field.

CIRCLE M STAMP

Fig. 1

METHODS OF SAMPLING AND TESTING
MT 111-04
SAMPLING, INSPECTION AND REPORTING ON PRESTRESSED CONCRETE BEAMS AND PILES

1 Scope:

1.1 This method is intended for the purpose of establishing a uniform procedure for the sampling, inspection and reporting of pre-stressed concrete beams and piles.

2 Referenced Documents:

2.1 ***MT Manual:***
MT-101 Making and Curing Compressive and Flexural Strength Test Specimens
MT-108 Sampling and Certification of Portland Cement
MT-201 Sampling Roadway Materials

3 Materials:

3.1 Materials used in the manufacture of pre-stressed beams will be covered individually to avoid any misunderstanding on the part of the Plant Inspectors.

3.1.1 Aggregates will be sampled and tested yearly in accordance with MT-201. One set of samples shall represent each new project ((one set of minus 4.75 mm (No. 4 mesh) and one set of minus 19.0 mm (3/4") aggregate)).

3.1.2 Cement will be accepted by certificate in conformance with MT-108, Sampling and Certification of Portland Cement, except that the certification, which accompanies the shipment of cement, shall be kept at the plant where the material is being fabricated. The certificate will be picked up by the Plant Inspector who is charged with the responsibility of making the inspection of the pre-stressed concrete beams and piles, and kept on file in the district laboratory.

3.1.3 Wire strand and reinforcing steel will be tested in the Materials Bureau. The samples will be submitted with a copy of the mill test results of the load elongation curve. When shipments of strand are received at the pre-stress plant, each reel will be sampled by obtaining approximately a ten foot long piece of each reel in the shipment. These samples together with reel numbers, heat numbers, and all available information such as size, strength, etc., will be submitted to the Materials Bureau for testing and no strand or any other item or ingredient used in the manufacture of beams, or piles, is to be used until a report of acceptance has been received by the Plant Inspector.

3.1.4 Reinforcing steel will be sampled as each new shipment arrives at the plant. Two samples of each size bar, approximately 76.2 mm (30") long, shall be submitted to the Materials Bureau. All of the pertinent information available shall be shown on the accompanying reports.

3.1.5 Cylinders representing release breaks will be made by the pre-stress plant personnel and witnessed by MDT. Twenty-eight day strength testing will be in accordance with MT-101. A set of 3 cylinders (28-day breaks) will be fabricated for each beam. Release cylinders will be made in sufficient numbers to perform the required tests prior to release of the strand.

3.1.6 Reports will be made to the field as soon as testing is complete. The test results will be sent to the Materials Bureau.

4 Acceptance:

4.1 Each pre-stress member that the Plant Inspector determines to conform to specification requirements in all respects will be marked with a Circle M stamp before shipment from the plant. This identifying mark will indicate that fabrication procedures, quality of materials and workmanship are satisfactory and the member is complete at the plant.

4.2 Absence of a Circle M stamp will indicate a member is not complete, requires corrective work, or that the inspector was not present at the time the member was loaded on the truck for shipment. Deficiencies observed by the Plant Inspector will be noted on the Pre-stress Beam - Final Plant Inspection Check List. Noted deficiencies not corrected before shipment will be transmitted to the field with the Pre-stress Beam Report Lab. Form No. 48.

4.3 Members will be inspected at the job site for shipping or handling damage or other defects. The contractor will be notified of any deficiencies as soon as practical.

4.4 Final acceptance of the member will be made in the field in accordance with applicable sections of Standard Specifications.

5 Inspection Report:

5.1 The Plant Inspector will send an inspection report with each beam sent to the project, with copies to the District Office, the Construction Bureau and the Materials Bureau. This report will state that all of the materials that make up the completed beams are covered by acceptable reports that are in the possession of the Plant Inspector. The report will identify the beams by number and will be placed in the report file as an indication that the beams are completed and are acceptable subject to final field inspection. .

5.2 A supply of Lab. Form No. 48 "Pre-stressed Beam Report" and "Pre-stress Beam - Final Plant Inspection Check List" has been supplied by the Materials Bureau for the convenience of the Plant Inspectors in complying with the above requirements.

MBF Form 48-A
(4-81)

PRESTRESS BEAM - FINAL PLANT INSPECTION CHECK LIST

PROJ. NO.: DESIGNATION

PLANT: INSPECTOR:

DATE CAST: DATE INSP.: DATE RE-INSP.:

ITEM	INITIAL INSP. Sat.	Unsat.	DESCRIPTION AND LOCATION	CORRECTED Yes	No
ENDS TRUE					
END FINISH					
CHAMFERS					
ROCK POCKET REPAIRS					
SURFACE DEFECT REPAIRS					
HOLD DOWN HOLES					
BOTTOM FLANGE FINISH					
EXT. BEAM FINISH					
DIMENSION TOLERANCES					
SHEAR REBAR HEIGHT					
BEARING PLATES					
OTHER (LIST)					
Stamped With Circle M Yes ____ No ____					

Instructions - Final Plant Inspection to be performed when plant foreman or supervisor advises that member is complete. Complete check list during inspection. Furnish copy to plant foreman. Do not apply circle M until all corrections are made. Attach copy to Lab Form No. 48.

METHODS OF SAMPLING AND TESTING
MT 113-04
MEASURING THE TEXTURE DEPTH OF PORTLAND CEMENT CONCRETE PAVEMENT
(Modified AASHTO T 261)

1 Scope:

1.1 This method describes the procedure for measuring texture depth of fresh or hardened concrete by using a tire tread depth gauge.

1.2 The values stated in SI units are to be regarded as the standard.

2 Referenced Documents:

2.1 ***AASHTO:***
T 261 Measuring Texture Depth of Portland Cement Concrete Using a Tire Tread Depth Gauge

3 Apparatus:

3.1 *Tire Tread Depth Gauge* – A tire tread depth gauge with 1 mm (1/32 in.) graduations similar to the one shown in Figure 1. The gauge end may be modified to a shape suitable for the measurement.

3.2 Wire or stiff bristle brush, carborundum stone.

3.3 Steel straightedge approximately 6 by 25 by 300 mm (1/4 by 1 by 12 in.)

3.4 30 m (100 ft.) tape.

4 Selection of Test Locations:

4.1 The lot size represented by the testing shall be as required by the specifying agency.

4.2 The lot shall be subdivided into five approximately equal sublots and one test area location shall be selected for each sublot at random. The random location shall be identified transversely and longitudinally.

5 Procedure:

5.1 Document the nature and purpose of the measurement (inspection of new construction, condition survey, safety review, etc.); include the date of measurement, test area location, the position within the lane (wheelpath or outside wheelpath), whether the concrete is fresh (plastic), hardened without traffic, or approximate time that the pavement has been opened to traffic. Note whether the texture was constructed by grinding or tining.

5.2 At each test area measure the texture depth of 10 consecutive grooves. The test location of each groove shall be in line perpendicular to the grooves, starting at the point randomly located in accordance with Section 4.2.

5.3 The texture depth shall be measured from the original concrete surface. Any projections above the original surface shall be removed by brushing with a wire brush or carborundum stone as necessary to remove ridges adjacent to grooving, or with the steel straigthtedge prior to taking a measurement on hardened concrete. If measurements are being made on fresh concrete, the depth gauge guide shall be pressed down to the level of the original concrete surface.

5 Procedure: (continued)

5.4 With the depth gauge guides in contact with the original concrete surface, the plunger is depressed until contact is made with the bottom of the groove in the concrete. The gauge is then removed without disturbing the plunger. The texture depth is read to the nearest 1 mm (1/32 in.) on the calibrated plunger. The plunger is then zeroed and the procedure is repeated until all measurements are completed.

6 Calculations:

6.1 Calculate the average groove depth for each of the five sublots.

6.2 Calculate the average groove depth for each lot to the nearest 1 mm (1/32 in.).

7 Report:

7.1 The report shall indicate the lot identification and the average groove depth to the nearest 1 mm (1/32 in.).

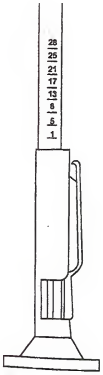


Figure 1—Depth Measuring Gauge

METHODS OF SAMPLING AND TESTING
MT 114-04
METHOD OF SAMPLING FOR CHLORIDE CONTENT OF BRIDGE DECK CONCRETE

1 Scope:

1.1 This is a method of sampling bridge deck concrete for chloride content.

2 Apparatus:

2.1 Coring Machine

2.2 Pachometer - A pachometer is available upon request from the Materials Bureau.

2.3 Gas powered (110-115 Volt A.C.) generator with transport cart for operating drill.

2.4 Rotary - impact drill of heavy duty construction.

2.5 Bit - 3/4 inch (19mm) diameter carbide steel bit.

2.6 Rubber "blow-out" bulb.

2.7 Pliable sampling spoon - Copper or flexible spoon 3 inches (7.5mm) in length and less than 3/4 inch (19mm) in width.

2.8 Plastic bottles - Approximately 2 inches (50mm) tall and 1 inch diameter with sealable caps.

2.9 Ruler with .10" increments and millimeters

2.10 Paper labels

2.11 "Set 45", "Rockite" or other fast setting grout.

2.11 Plastic goggles, hearing protection, gloves

2.12 Plastic bottle containing one of the following: distilled water, deionized water, ethanol (denatured) or methanol (technical grade).

2.15 See MDT Safety Policies and Procedures Manual.

3 Sampling:

3.1 Chloride samples shall be taken before coring and in an area as close as possible and with the same types of distress (i.e. delaminations or cracking) as that intended for coring.

3.2 When coring or sampling for chlorides extreme caution will be required due to traffic hazards and use of power equipment. For standard safety practices refer to the MDT Safety Policies and Procedures Manual.

4 Procedure:

4.1 The Bridge Plans are used to find approximate rebar location, cover over rebar, and thickness of concrete.

4.2 The pachometer is used to locate top layer of reinforcing steel and its depth.

4.3 Drill a hole 1/4 inch (6mm) deep and discard this portion of the sample by using the "blow-out" bulb. (See Note 1)

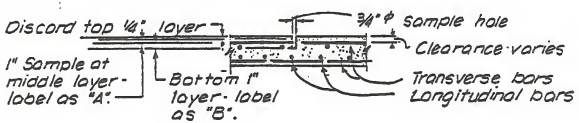
4.4 Drill the hole to a depth corresponding to the top of the rebar (see Note 1 and 2) and use copper spoon to collect minimum 10 g sample in plastic bottle labeled "A".

4.5 Blow the hole clean with "blow-out" bulb.

4.6 Drill hole to a depth of one inch below the top layer of reinforcing steel. Secure minimum 10 g sample of pulverized concrete with copper spoon and place into plastic bottle labeled as "B". (See Note 1 and 2)

4.7 Clean holes and fill with high strength epoxy grout patching compound such as "Set 45" or "Rockite".

Note 1 - The sketch as shown below defines the drilling depth for sampling:



CROSS SECTION THROUGH SLAB

Note 2 - During sample collection and pulverizing, personnel shall use caution to prevent contact of the sample with hands or other sources of body perspiration or contamination. Further, all sampling tools (drill bits, spoons, bottles, sieves, etc.) shall be washed with alcohol or distilled water and shall be dry prior to use on each separate sample. Alcohol is normally preferred for washing because of the rapid drying which naturally occurs.

5 Labeling:

5.1 The following data will be written on each label and attached to each sample bottle:

5.1.1 Project number and termini

5.1.2 E.B. or W.B. lane

5.1.3 Position in lane measured from curb

5 Labeling: (continued)

5.1.4 Depth range of sample measured from top of deck and labeled as "A" or "B"; (See Note 1)

5.1.5 Depth of reinforcing steel

5.1.6 Core number cross reference

5.1.7 Brief description of condition of area (i.e., delaminations, cracks).

6 Submittal:

6.1 Cores with chloride samples will be submitted to the Materials Bureau.

METHODS OF SAMPLING AND TESTING
MT 115-04
WEIGHT PER CUBIC FOOT, YIELD, AND AIR CONTENT (GRAVIMETRIC) OF CONCRETE
(Modified AASHTO T121)

1 Scope:

1.1 This method covers determination of the weight per cubic foot (or cubic meter) of freshly mixed concrete and gives formulas for calculating the yield, cement content, and the air content of the concrete. Yield is defined as the volume of concrete produced from a mixture of known quantities of the component materials.

1.2 The values stated in in-pound units are to be regarded as the standard.

2 Referenced Documents:

2.1 ***AASHTO:***

M 85 Portland Cement
T 121 Mass per Cubic Meter (Cubic Foot), Yield, and Air Content (Gravimetric) of Concrete
T 133 Specific Gravity of Hydraulic Cement

MT Manual:

MT-102 Air Content of Freshly Mixed Concrete by Pressure Method
MT-105 Sampling Fresh Concrete
MT-203 Unit Weight of Aggregate

3 Symbols:

A = air content (percentage of voids) in the concrete
N = actual cement content, lb/yd³ or kg/m³
N_f = mass of cement in the batch, lb or kg
R_y = relative yield
T = theoretical weight of the concrete computed on an airfree basis, lb/ft³ or kg/m³ (Note 1)
V = total absolute volume of the component ingredients in the batch, ft³ or M³
W = unit of mass of concrete, lb/ft³ or kg/m³
W_f = total mass of all materials batched, lb or kg (Note 2)
Y = volume of concrete produced per batch, yd³ or m³
Y_d = volume of concrete which the batch was designed to produce, yd³ (m³)
Y_f = volume of concrete produced per batch, ft³

Note 1 - The theoretical weight per cubic foot or cubic meter is, customarily, a laboratory determination, the value for which is assumed to remain constant for all batches made using identical component ingredients and proportions. It is calculated from the equation:

$$T = W_f / V$$

The absolute volume of each ingredient in cubic feet is equal to the quotient of the mass of that ingredient divided by the product of its specific gravity times 62.4. The absolute volume of each ingredient in cubic meters is equal to the mass of the ingredient in kilograms divided by 1,000 times its specific gravity. For the aggregate components, the bulk specific gravity and mass should be based on the saturated, surface-dry condition. For cement, the actual specific gravity should be determined by Test Method T 133. A value of 3.15 may be used for cements manufactured to meet the requirements of Specification M 85.

Note 2 -The total weight of all materials batched is the sum of the weights of the cement, the fine aggregate in the condition used, the coarse aggregate in the condition used, the mixing water added to the batch and any other solid or liquid materials used.

4 Apparatus:

4.1 *Balance* - A balance or scale accurate to within 0.3% of the test load at any point within the range of use. The range of use shall be considered to extend from the weight of the measure empty to the weight of the measure plus its contents at 160 lb/ft³ (2,600 kg/m³).

4.2 *Tamping Rod* - A round straight steel rod, _ in. (16 mm) in diameter and approximately 24 in. (60 mm) in length, having the tamping end rounded to a hemispherical tip the diameter of which is _ in.

4.3 *Internal Vibrator* - Internal vibrators may have rigid or flexible shafts, preferably powered by electric motors. The frequency of vibration shall be 7,000 vibrations per minute or greater while in use. The outside diameter or the side dimension of the vibrating element shall be at least 0.75 in. (19 mm) and not greater than 1.50 in. (38 mm). The length of the shaft shall be at least 24 in. (600 mm).

4.4 *Measure* - A cylindrical container made of steel or other suitable metal (Note 3). It shall be watertight and sufficiently rigid to retain its form and calibrated volume under rough usage. Measures that are machined to accurate dimensions on the inside and provided with handles are preferred. The minimum capacity of the measure shall conform to the requirements of Table 1. All measures, except for measuring bowls of air meters that are used for Method T 121 tests, shall conform to the requirements of Test Method MT-203. When measuring bowls of air meters are used, they shall conform to the requirements of Test MT-102. The top rim of the air meter bowls shall be smooth and plane within 0.01 in. (0.25 mm).

Note 3 -The metal should not be readily subject to attack by cement paste. However, reactive materials such as aluminum alloys may be used in instances where as a consequence of an initial reaction, a surface film is rapidly formed which protects the metal against further corrosion.4

Note 4 -The top rim is satisfactorily plane if a 0.01 in. (0.25 mm) feeler gage cannot be inserted between the rim and a piece of ¼ in. (6 mm) or thicker plate glass laid over the top of the measure.

4.5 *Strike-Off Plate* - A flat rectangular metal plate at least ¼ in. (6 mm) thick or a glass or acrylic plate at least ½ in. (12 mm) thick with a length and width at least 2 in. (50 mm) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of 1/16 in. (1.5 mm).

4.6 *Calibration Equipment* - A piece of plate glass, preferably at least ¼ in.(6 mm) thick and at least 1 in. (25 mm) larger than the diameter of the measure to be calibrated. A supply of water pump or chassis grease that can be placed on the rim of the container to prevent leakage.

4.7 *Mallet* - A mallet (with a rubber or rawhide head) weighing approximately 1.25 ± 0.50 lb (0.57 ± 0.23 kg) for use with measures of 0.5 ft.³ (14 dm³) or smaller, and a mallet weighing approximately 2.25 ± 0.50 lb (1.02 ± 0.23 kg) for use with measures larger than 0.5 ft³.

Apparatus: (continued)

TABLE 1 - Capacity of Measures

Nominal Maximum Size of Coarse Aggregate [a]		Capacity of Measure [a]	
in.	mm	ft^3	L
1	25.0	0.2	6
1½	37.5	0.4	11
2	50	0.5	14
3	75	1.0	28
4½	112	2.5	70
6	150	3.5	100

[a] *The indicated size of measure shall be used to test concrete containing aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95 percent of the nominal volume listed.*

5 Calibration of Measure:

5.1 Calibrate the measure and determine the factor used to convert the mass in pounds (or kilograms) contained in the measure to mass in pounds per cubic foot (or kilograms per cubic meter). Follow the procedure outlined in MT-203. Measures shall be recalibrated at least once a year or whenever there is reason to question the accuracy of the calibration.

6 Sample:

6.1 Obtain the sample of freshly mixed concrete in accordance with MT-105.

7 Procedure:

7.1 The methods of consolidation are rodding and internal vibration. Rod concretes retain with a slump greater than 3 in. (75 mm). Rod or vibrate concrete with a slump of 1 to 3 in. (25 to 75 mm). Consolidate concretes with a slump less than 1 in. (25 mm) by vibration.

Note 5 - The non-plastic concrete, such as is commonly used in the manufacture of pipe and unit masonry, is not covered by this method.

7.2 *Rodding* - Place the concrete in the measure in three layers of approximately equal volume. Rod each layer with 25 strokes of the tamping rod when the 0.5 ft^3 (14 dm^3) or smaller measures are used and 50 strokes when the 1 ft^3 (28 dm^3) measure is used. Rod the bottom layer throughout its depth but the rod shall not forcibly strike the bottom of the measure. Distribute the strokes uniformly over the cross section of the measure and for the top two layers, penetrate about 1 in. (25 mm) into the underlying layer. After each layer is rodded, tap the sides of the measure smartly 10 to 15 times with the appropriate mallet (see 3.7) to close any voids left by the tamping rod and to release any large bubbles of air that may have been trapped. Add the final layer so as to avoid overfilling.

7.3 *Internal Vibration* - Fill and vibrate the measure in two approximately equal layers. Place all of the concrete for each layer in the measure before starting vibration of that layer. Insert the vibrator at three different points of each layer. In compacting the bottom layer, do not allow the vibrator to rest on or touch the bottom or sides of the measure. In compacting the final layer, the vibrator shall penetrate into the underlying layer approximately 1 in. (25 mm). Take care that the vibrator is withdrawn in such a manner that no air pockets are left in the specimen. The duration of vibration required will depend upon the workability of the concrete and the effectiveness of the vibrator (Note 6). Continue vibration only long enough to achieve proper consolidation of the concrete

7 Procedure: (continued)

(Note 7). Observe a constant duration of vibration for the particular kind of concrete, vibrator, and measure involved.

Note 6 - Usually, sufficient vibration has been applied as soon as the surface of the concrete becomes relatively smooth.

Note 7 – Over vibration may cause segregation and loss of appreciable quantities of intentionally entrained air.

7.4 On completion of consolidation the measure must not contain a substantial excess or deficiency of concrete. An excess of concrete protruding approximately 1/8 in. (3 mm) above the top of the mold is optimum. A small quantity of concrete may be added to correct a deficiency. If the measure contains a great excess of concrete at completion of consolidation, remove a representative portion of the excess concrete with a trowel or scoop immediately following completion of consolidation and before the measure is struck-off.

7.5 *Strike-Off* - After consolidation, strike-off the top surface of the concrete and finish it smoothly with the flat strike-off plate using great care to leave the measure just level full. The strike-off is best accomplished by pressing the strike-off plate on the top surface of the measure to cover about two-thirds of the surface and withdrawing the plate with a sawing motion to finish only the area originally covered. Then place the plate on the top of the measure to cover the original two-thirds of the surface and advance it with a vertical pressure and a sawing motion to cover the whole surface of the measure. Several final strokes with the inclined edge of the plate will produce a smooth finished surface.

7.6 *Cleaning and Weighing* - After strike-off, clean all excess concrete from the exterior of the measure and determine the net mass of the concrete in the measure to an accuracy consistent with the requirements of 4.1.

***Note 8** - A value for R_y greater than 1.00 indicates an excess of concrete being produced, whereas a value less than this indicates the batch to be "short" of its designed volume.*

8 Calculations:

8.1 *Unit Weight* - Calculate the net mass of the concrete in pounds or kilograms by subtracting the mass of the measure from the gross mass. Calculate the unit mass, *W*, by multiplying the net mass by the calibration factor for the measure used, determined according to Test Method MT-203.

8.2 *Yield* - Calculate the yield as follows:

$Y_f(ft^3) = W_1 / W$

or,

$Y(yd^3) = W_1 / 27\ W$

or,

$Y(m^3) = W_1 / W$

8.3 *Relative Yield* - Relative yield is the ratio of the actual volume of concrete obtained to the volume as designed for the batch calculated as follows:

$R_y = Y / Y_d$

8 Calculations: (continued)

8.4 *Cement Content* - Calculate the actual cement content as follows:

$N = N_f / Y$

8.5 *Air Content* - Calculate the air content as follows:

$A = [(T - W)/T] \times 100$

or,

$A = [(Y_f - V)/Y_f] \times 100$ (Inch-pound units)

or,

$A = [(Y - V)/Y] \times 100$ (SI units)

BACK

CURRENT DATE OF REVISION
MT-200 SECTION (SOIL AND AGGREGATE)

Test Method No.	Title	Pages	Date of Publication or Revision
MT-200	Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test	pp 1-4	May 2004
MT-201	Sampling Roadway Materials	pp 1-8	May 2004
MT-202	Sieve Analysis for Fine and Coarse Aggregate	pp 1-7	May 2004
MT-203	Unit Weight of Aggregate	pp 1-6	May 2004
MT-204	Specific Gravity and Absorption of Fine Aggregate	pp 1-5	May 2004
MT-205	Specific Gravity and Absorption of Coarse Aggregate	pp 1-7	May 2004
MT-206	Terms Relating to Density and Specific Gravity of Solids, Liquids and Gases	pp 1-3	May 2004
MT-207	Centerline Soil Survey	pp 1-12	May 2004
MT-208	Determining the Liquid Limit, the Plastic Limit, and the Plasticity Index of Soils	pp 1-10	May 2004
MT-209	Los Angeles Abrasion (Wear Test)	pp 1-4	May 2004
MT-210	Moisture-Density Relations of Soils Using a 5.5 lb. Rammer and a 12 In. Drop	pp 1-7	May 2004
MT-211	Moisture-Density Relations of Soil-Cement Mixtures	pp 1-6	May 2004
MT-212	Determination of Moisture and Density of In-Place Materials	pp 1-5	May 2004
MT-213	Plastic Fines in Graded Aggregates (Sand Equivalent Test)	pp 1-8	May 2004
MT-214	The Classification of Soil and Soil-Aggregate Mixtures	pp 1-8	May 2004
MT-215	Moisture Content by Calcium Carbide Method	pp 1-3	May 2004
MT-216	Method of Sampling and Testing Cement Treated Base	pp 1-3	May 2004
MT-217	Method for Determining Percentage of Mechanically Fractured Particles	pp 1-5	May 2004
MT-218	Determining Relative Compaction and Percent Moisture	pp 1-2	May 2004
MT-219	Controlling Compaction Using a Control-Strip Test-Section Technique with Nuclear Gauges	pp 1-5	May 2004
MT-220	Specific Gravity of Soils	pp 1-5	May 2004
MT-221	Vacant		
MT-222	Vacant		
MT-223	Clay Lumps and Friable Particles in Aggregates	pp 1-3	May 2004
MT-224	Vacant		
MT-225	Failing and Check Samples of Aggregates	pp 1-2	May 2004
MT-226	Maximum Acceptable Deviations in Sieve Analysis of IA Samples	pp 1-7	May 2004

Test Method No.	Title	Pages	Date of Publication or Revision
MT-227	Method of Test for Determination of Moisture Content of Soils	pp 1-2	May 2004
MT-228	Method of Test for Evaluating Cleanness of Cover Coat Material	pp 1-4	May 2004
MT-229	Procedure for Solids-Water-Voids Relations of Soil Masses	pp 1-9	May 2004
MT-230	Moisture-Density Relation of Soils Using a 10 lb Rammer and 18 In. Drop	pp 1-8	May 2004
MT-231	Procedure for Correction for Coarse Particles in the Soil Compaction Test	pp 1-5	May 2004
MT-232	Soil Corrosion Test	pp 1-3	May 2004

METHODS OF SAMPLING AND TESTING
MT 200-04
DRY PREPARATION OF DISTURBED SOIL AND SOIL AGGREGATE SAMPLES FOR TEST
(Modified AASHTO T 87)

1 **Scope:**

1.1 This method describes the dry preparation of soil and soil-aggregate samples, as received from the field, for mechanical analysis, physical tests, moisture-density relations test, and other tests as may be desired.

2 **Apparatus:**

2.1 *Balance* - A balance sensitive to 0.1 g for samples weighing approximately 110 g or less; for larger samples, the balance shall be sensitive to within 0.1 percent of the sample to be weighed.

2.2 *Drying Apparatus* - Any suitable device capable of drying samples at a temperature not exceeding 60 C (140 F),

2.3 *Sieves* - A series of sieves of the following sizes: 19.0 mm (¾ in.), 4.75 mm (No. 4), 2.00 mm (No. 10), 0.425 mm (No. 40) and others as required for preparing the sample for a specific test. The sieves shall conform to MT-405, Sieves for Testing Purposes.

Note 1 - A 50 mm (2 in.) sieve is required if the sample includes particles retained on the 10.0 mm (¾ in.) sieve and it is desired that the sample for moisture-density relations (AASHTO T 99 or T 180) contain material between 19.0 mm (¾ in.) and 4.75 mm (No. 4) sieve size to represent the fraction between 50 and 19.0 mm (2 in. and ¾ in.).

2.4 *Pulverizing Apparatus* - Either a mortar and rubber-covered pestle or a mechanical device consisting of a power-driven rubber-covered muller suitable for breaking up the aggregations of soil particles without reducing the size of the individual grains.

Note 2 - Other types of apparatus, such as a revolving drum into which the soil sample and rubber-covered rollers are placed and tumbled until soil aggregations are pulverized, are satisfactory if the aggregations of soil particles are broken up without reducing the size of the individual grains.

2.5 *Sample Splitter* - A suitable riffle sampler or sample splitter for proportional splitting of the sample and capable of obtaining representative portions of the sample without appreciable loss of fines. The width of the container used to feed the riffle sample splitter should be equal to the total combined width of the riffle chutes. Proportional splitting of the sample on a canvas cloth is also permitted.

Note 3 - The procedure for proportional splitting is described in MT-417, Reducing Field Samples of Aggregate to Testing Size.

3 **Sample Size:**

3.1 The amounts of soil material required to perform the individual tests are as follows:

3.1.1 *Particle Size Analysis of Soils* (AASHTO T 88)-- For the particle size analysis material passing a 2.00 mm (No. 10) sieve is required in amounts equal to approximately 110 g for sandy soils and approximately 60 g of silty or clayey soils. A sufficient amount of material retained on either the 4.75 mm (No. 4) sieve or 2.00 mm (No. 10) sieve is required (Note 4) to obtain a representative gradation, and depending on the maximum particle size, shall not be less than the amount shown in the following table:

3 Sample Size: (continued)

Diameter of Largest Particle, mm (in.)	Approximate Minimum Mass of Portion, kg
9.5 (3/8)	0.5
25.0 (1)	2.0
50 (2)	4.0
75 (3)	5.0

Note 4 - The material for coarse sieve analysis may be separated by either of two alternate methods, 4.2.1 (2.00 mm sieve) or 4.2.2 (4.75 mm sieve). When only a small percentage of the material will be retained on the 4.75 mm or 2.00 mm sieve, a considerable total weight of sample will be required to provide the minimum quantity shown in the above table; consequently, if the material represented by the sample is not to be used in a base or sub-base course, select borrow, or other item having a requirement for coarse aggregate adherence to the minimum weight requirements in the above table may not be necessary.

3.1.2 *Specific Gravity (AASHTO T 100)* - For the specific gravity test performed in conjunction with AASHTO T 88, Mechanical Analysis, Soils, Material passing the 2.00 mm (No. 10) sieve is required in the amounts (oven-dry) of at least 25 g when the volumetric flask is used and at least 10 g when the stoppered bottle is used.

3.1.3 *Physical Tests* - For the physical tests, material passing the 0.425 mm (No. 40) sieve is required in the total amount of at least 300 g, allocated approximately as follows:

Test (and AASHTO Designation)	Approx. Mass, g.
Liquid limit (T 89)	100
Plastic limit (T 90)	20
Shrinkage factors (T 92)	30
Field moisture equivalent (T 93)	50
Check the referee tests	100

3.1.4 *Moisture-Density Relations (MT-210)* - For moisture-density relations test, the following approximate amounts of material are required:

Method	Soil Material Passing, Sieve	Approximate Quantity Required mm	lb.	kg.
A	4 Mesh	4.75	7	3.2
B	4 Mesh	4.75	16	7.3
C	3/4 Inch	19.00	12	5.4
D	3/4 Inch	19.00	25	11.3

3.1.5 *Other Tests* - For quantity of material required for testing, refer to the specific method of test.

4 Initial Preparation of Test Samples:

4.1 The soils sample as received from the field shall be dried thoroughly in air or the drying apparatus at a temperature not exceeding 60 C (140 F). A representative test sample of the amount required to perform the desired tests (Section 3) shall then be obtained with the sampler, or by splitting or quartering. The aggregations of soil particles shall then be broken up in the pulverizing apparatus in such a way as to avoid reducing the natural size of individual particles.

Note 5 - Samples dried in an oven or other drying apparatus at a temperature not exceeding 60 C (140 F) are considered to be air dried.

4 **Initial Preparation of Test Samples:** (continued)

4.2 The portion of the dried sample selected for particle size analysis and physical tests (including specific gravity) shall be weighed and that weight recorded as the weight of total sample uncorrected for hygroscopic moisture. This portion shall then be separated into fractions by one of the following methods:

4.2.1 *Alternate Methods Using 2.00 mm (No. 10) Sieve* - The dried sample shall be separated into two fractions using a 2.00 mm sieve. the fraction retained on the sieve shall be ground with the pulverizing apparatus until the aggregations of soil particles are broken into separate grains. The ground soil shall then be separated into two fractions using the 2.00 mm sieve.

4.2.2 *Alternate Method Using 4.75 mm and 2.00 mm (No. 4 and No. 10) Sieves* - The dried sample shall first be separated into two fractions using a 4.75 mm sieve. The fraction retained on this sieve shall be ground with the pulverizing apparatus until the aggregation of soil particles are broken into separate grains, and again separated on the 4.75 mm sieve. The fraction passing the 4.75 mm sieve shall be mixed thoroughly and, by the use of the sampler or by splitting and quartering, a representative portion adequate for the desired tests shall be obtained and weighed. This split-off portion shall then be separated on the 2.00 mm sieve, and processed as in 4.2.1. The material from the split-off fraction that is retained on the 2.00 mm sieve shall be weighed for later use in coarse sieve analysis computations.

5 **Test Sample for Particle Size Analysis and Specific Gravity:**

5.1 The fraction retained on the 2.00 mm (No. 10) sieve in 4.2.1 or that retained on the 4.75 mm (No. 4) sieve in 4.2.2, after the second sieving, shall be set aside for use in sieve analysis of the coarse material.

5.2 The fraction passing the 2.00 mm (No. 10) sieve in both sieving operations in 4.2.1 or 4.2.2 shall be thoroughly mixed together and, by the use of the sampler or by splitting or quartering, representative portions having approximate weights as follows shall be obtained: (1) for the hydrometer analysis and sieve analysis of the fraction passing the 2.00 mm sieve, 110 g for sandy soil and 60 g for silty or clayey soils; and (2) for specific gravity, 25 g when the volumetric flask is to be used and 10 g when the stoppered bottle is to be used.

6 **Test Sample for Physical Tests:**

6.1 The remaining portion of the material passing the 2.00 mm (No. 10) sieve shall then be separated into two parts by means of a 0.425 mm (N. 40) sieve. The fraction retained on the 0.425 mm (No. 40) sieve shall be ground with the pulverizing apparatus in such a manner as to break up the aggregations without fracturing the individual grains. If the sample contains brittle particles, such as flakes of mica, fragments of sea shells, etc., the pulverizing operation shall be done carefully and with just enough pressure to free the finer material that adheres to the coarser particles. The ground soil shall then be separated into two fractions by means of the 0.425 mm (N. 40) sieve and the material shall be reground as before. When repeated grinding produces only a small quantity of soil passing the No. 40 sieve, the material retained on the No. 40 sieve shall be discarded. The several fractions passing the No. 40 sieve obtained from the grinding and sieving operations just described shall be thoroughly mixed together and set aside for use in performing the physical tests.

7 **Test Sample for the Moisture Density Relations:**

7.1 The portion of dried soil selected for the moisture-density relations test shall be separated by means of the required sieve as specified in Section 3.1.4. If necessary, the pulverizing apparatus shall be used to break up the soil aggregations retained on this sieve into separate grains. The ground soil shall then be separated into two fractions using the required sieve.

7 **Test Sample for the Moisture Density Relations:** (continued)

7.2 The fraction retained on the sieve after the second sieving shall be saved, if required. The fractions passing the required sieve in both sieve operations shall be thoroughly mixed and used for the moisture-density test.

METHODS OF SAMPLING AND TESTING
MT 201-04
SAMPLING ROADWAY MATERIALS

1 General:

1.1 Sampling for evaluation of potential aggregate sources should be performed by a responsible, trained and experienced person. Because of the wide variety of conditions under which sampling may be done, it is not possible to describe detailed procedures applicable to all circumstances.

1.1.1 The sample bags must be tightly-woven and durable so that the required amount of sample can be shipped without rupture of the bag or loss of fine material through the fabric. Also, when tied as in 1.2., the bag must be sealed tightly enough to prevent loss or contamination of the material. The Materials Bureau uses a 14 oz. (397 grams) tightly-woven canvas bag conforming to the following: unfinished size shall be 29 X 36 inches (725 X 900mm), finished size shall be 28 X 17 inches (700 X 425mm), seams shall be double stitched with right and left twist application using heavy duty #D-E weight B-277 bonded thread. Also, the bags are top-opening, no closure with a cut, non-fraying edge.

1.2.1 Samples shall be double tied as close to the gravel as possible with the necessary papers between the double tie. This procedure insures a good sample together with a legible laboratory sheet.

2 Referenced Documents:

2.1 ***MT Manual:***

MT-202 Sieve Analysis of Fine and Coarse Aggregate
MT-207 Centerline Soil Survey
MT-210 Moisture Density Relation of Soils Using a 5.5 lb. Rammer
MT-218 Determining Relative Compaction and Percent Moisture
MT-216 Method of Sampling and Testing Cement Treated Base
MT-230 Moisture Density Relation of Soils Using a 10 lb. Rammer
MT-417 Procedure for Reducing Filed Samples to Testing Size
MT-601 Materials Sampling, Testing and Acceptance Guide

3 Number of Samples:

3.1 The frequency of sampling as described in this procedure is the minimum required and more should be taken if deemed necessary.

4 Pre-construction Proposed Surfacing Sampling:

4.1 Proposed surfacing samples should represent a vertical cross-section of the proposed source.

4.1.1 Color pictures of the terrain and test holes should be made as part of the prospecting procedure. Photographs should be dated and a description of the photograph's location and direction should be placed on the back of the photograph for the permanent site record.

4.1.2 Describe each site or area investigated with each test hole, boring or test pit clearly located (horizontally and vertically) with reference to some established coordinate system or permanent monument on an area map or sketch.

4 Pre-construction Proposed Surfacing Sampling: (continued)

4.1.3 Log each test hole, boring, test pit or cut-surface exposure with the field description and location of each material encountered clearly shown by Montana Department of Highways' symbols and word descriptions used on Form 30. An example of Form 30 is in MT-207.

4.1.4 Each aggregate layer that is included in the sample should be noted along with the depth of the water table if it is encountered should be shown on the log of test holes.

4.2 Overburden or clay seams shall be sampled separately.

4.3 Rocks larger than 6 inches (150mm) in diameter shall not be included in the sample. However, the estimated percentage of rock larger than 12 inches (300mm); between 6 and 12 inches (150 and 300mm); between 4 and 6 inches (100 and 150mm); and less than 4 inches (100mm) in diameter shall be shown on the Prospected Area Report.

4.4 Representative samples shall be taken on the following basis:

4.4.1 Each sample shall be a minimum of 150 pounds (68 Kg).

4.4.2 Not less than 3 samples shall be taken from any proposed source.

4.4.3 Up to 50,000 cubic yards (38,230 cubic meters) - a minimum of 3 samples.

4.4.4 50,000 to 100,000 cubic yards (38,230 to 76,460 cubic meters) - 3 to 5 samples.

4.4.5 100,000 to 150,000 cubic yards (76,460 to 114,690 cubic meters) - 5 to 8 samples.

4.4.6 150,000 to 200,000 cubic yards (114,690 to 152,920 cubic meters) - 8 to 10 samples.

3.4.7 Providing the material is uniform, one sample may represent material from as many as ten test holes in large areas if provisions 4.4.1. through 4.4.6. above, are met.

4.4.8 For large sources, a suggested sampling sequence is to take samples around the perimeter of the source with additional samples taken toward the middle to check for uniformity. Each proposed source is unique, however, and the final sampling sequence shall be determined by the District Materials Supervisor or Area Lab Supervisor.

4.5 The District or Area laboratory will determine the gradation, LL, PI, soil class and 24-hour volume swell and submit to the Materials Bureau on a form 123. Also, a visual examination by the Materials Supervisor will be made. An interpretation of these results will determine if the material in the proposed source is worthy of further consideration.

4.5.1 Predominately Unacceptable - If the tests show the material to be predominately unsatisfactory and material of a better quality is available, no further consideration shall be given this source.

4.5.2 Uniformly Acceptable - If the tests indicate the material is uniformly satisfactory, at least one sample for every six tested in the District or Area laboratory (a minimum of three) shall be sent to the Materials Bureau. Each sample shall consist of 1-75 lb. (34 Kg) split for wear, gradation and other correlations (see note 1). One 70 lb. (32 Kg) composite sample per source is required for "R" value. Also, 1-500 lb. (227 Kg) composite from each source for Modified Lottman is required.

4 Pre-construction Proposed Surfacing Sampling: (continued)

4.5.3 Spotty sources - If the tests indicate the material is spotty, at least one sample for every six tested in the District or Area laboratory (a minimum of one) for each of the areas (satisfactory, questionable, and unsatisfactory) shall be sent to the Materials Bureau for wear test, gradation check, evidence of disintegration, and other correlations. In addition, a 500 lb. (227 Kg) composite sample for Modified Lottman and a 70 lb. (32 Kg) composite sample for "R" value shall be submitted for each of these areas. The Modified Lottman and "R" value samples shall be composited as outlined in the table.

Number of Representative Pounds from Each Hole To Make Composite

Holes	"R" Value		Modified Lottman	
	lbs.	Kg	lbs.	Kg
2	70	32.0	250	113.4
5	14	6.4	100	45.4
10	7	3.2	50	22.7
15	5	2.3	34	15.4

Note 1 - Each area within a source that exhibits different physical characteristics should be sampled completely as per 4.5.2. In a large volume area one sample may be a composite of a series of holes of uniform material (example: sample number 1 may be a composite of holes 1 through 6; sample number 2 - holes 7 through 12; sample number 3 - holes 13 through 20, etc.) The example cited above is to be used as a guide only.

4.5.4 Material for each portion of the composite sample shall be obtained by quartering, splitting, recombining and splitting again according to MT-417 so that a homogenous mix is obtained. The material will be split so that no more than 77 lbs. (35 Kg) are placed in one bag.

4.5.5 The Core Drill Section, under the direction of the Geology Section, can be utilized in problem areas where conventional equipment is inadequate. Assistance, either geologic or drilling, can be provided usually within a period of a month or six weeks.

5 Laboratory Form No. 99:

5.1 The "Field Sample Analysis Report" Form No. 99 is to be used in reporting district or area laboratory tests. This information will be transferred to the "Available Surfacing Material Report" in Helena and will be available to prospective bidders, along with the usual Materials Bureau test results.

5.2 The District Materials Supervisor or Area Lab Supervisor is to use his experience and engineering judgment to give a summation of all information such as the past history of the source and his comments and recommendations regarding the laboratory test data which would include a statement as to which holes were represented by the Modified Lottman and "R" Value samples. This information will be placed on the bottom portion of Lab Form No. 99. However, the acceptance or rejection of the source will be the responsibility of the Materials Bureau in Helena when all testing is complete.

6 Laboratory Form No. 92:

6.1 The field information on Laboratory Form No. 92 shall include a correct legal description of the deposit. In some cases, it may be necessary to have a survey party retrace the boundary lines and make section line ties before right-of-way negotiations can be completed. Where deposits are located adjacent to the highway right-of-way, the boundary lines of the deposit should be tied to the centerline and shown on Laboratory Form No. 92 so that a legal description can be prepared without any further field work. Under some circumstances, the Department of Highways

6 **Laboratory Form No. 92:** (continued)
will obligate by purchase or option surfacing material sources for future construction projects and maintenance use.

6.2 Form No. 92 "Prospected Area Report" must be completely filled out especially with reference to definite location, total yardage represented by the samples, ownership, and depth of overburden. The haul distance shall be reported to the nearest one-tenth mile over the shortest and most practical route from the deposit to a definite station on the project.

6.3 A sketch shall be attached to Form 92 showing the boundary lines of the deposit with all dimensions and ties neatly plotted to a scale that is indicated on the sketch. All test holes shall be numbered and shown in their correct location.

6.4 In those cases where areas are being explored on which data has been previously submitted, a new "Prospected Area Report" shall accompany the new sampling showing any laboratory numbers previously assigned.

7 **Reports on Proposed Surfacing Sources:**

7.1 The Materials Bureau will issue a final report based on an evaluation of the district or area laboratory test data, the recommendations of the District Materials Supervisor or Area Lab Supervisor, and an interpretation of tests performed by the Materials Bureau.

8 **Preconstruction Binder Samples:**

8.1 Binder samples shall be taken incidental to all proposed gravel source exploration. A 25 lb. (11 Kg) sample from each distinct type proposed for use shall be taken and tested in the district or area laboratory. Binder samples need not be sent to the Materials Bureau unless an unusual problem arises.

9 **Size of Samples: Required for District, Area and Materials Bureau Testing:**

9.1 The sample size depends on 100% of the aggregate passing the specified sieve size. The amounts specified in the table below provide adequate material for routine testing (gradation, LL, PI, volume swell, etc.). Minimum Field Test sample sizes are in MT-202.

SPECIFIED 100% PASSING SIEVE SIZE	MINIMUM WEIGHT OF SAMPLE (See Note 3)
4.75 mm (4 Mesh)	14 Kg (30 lb.)
9.5 mm (3/8 Inch)	14 Kg (30 lb.)
12.5 mm (1/2 Inch)	14 Kg (30 lb.)
16.0 mm (5/8 Inch)	14 Kg (30 lb.)
19.0 mm (3/4 Inch)	14 Kg (30 lb.)
25.0 mm (1 Inch)	35 Kg (77 lb.)
37.5 mm (1½ Inch)	35 Kg (77 lb.)
50 mm (2 Inch)	35 Kg (77 lb.)
63 mm (2½ Inch)	35 Kg (77 lb.)

Note 3 - The sample shall be obtained by quartering or splitting to insure a representative sample. If necessary, the representative sample shall be split again so that no more than 77 lbs. (35 Kg) are placed in one bag.

10 **Sampling from Stockpiles:**

10.1 When such sampling is necessary, every effort should be made to enlist the services of power equipment to develop a separate, small sampling pile composed of materials drawn from various

10 Sampling from Stockpiles: (continued)

levels and locations in the main pile after which several increments may be combined to compose the field sample.

10.2 Coarse Aggregate Stockpiles - Where power equipment is not available, samples from stockpiles should be made up of at least three increments taken from the top third, at the midpoint, and at the bottom third of the volume of the pile. A board shoved vertically into the pile just above the sampling point aids in preventing further segregation.

10.3 Fine Aggregate Stockpile - A suggested sampling procedure for fine aggregate would be to remove the outer layer, which may have become segregated and take the sample from the material beneath. Sampling tubes approximately 1¼ inches (30-mm) minimum by 6 feet (2-m) minimum in length may be inserted into the pile at random locations to extract a minimum of five increments of material to form the sample.

11 Production Sampling:

11.1 Production samples shall be taken in three equal increments from a stopped belt or with an automatic sampling device and combined to make the sample. Such samples shall be reduced to testing size, according to MT-417, Method A or Method B.

12 Road or Windrow Sampling:

12.1 Samples should be composed of a number of samples taken at various points along the windrow, combined and reduced to testing size according to MT-417, Method A or Method B.

13 Pug Mill - Mixed Aggregate Sampling:

13.1 Samples for gradation and fracture testing shall be taken from the processed material after lay down.

13.2 Samples for crushed cover material gradation, fracture and cleanliness value will be taken at the most convenient point before application determined by the engineer.

13.3 Samples for other specified properties will be taken at the point of production.

14 Sampling from Roadway:

14.1 Samples from the roadway should be taken for the full depth of the material, taking care to exclude any underlying material. Where necessary, place templates on the existing roadway to separate the underlying material from the sample.

14.2 District or Area labs will determine the gradation, LL, PI and soil class for Soil Survey "R" Value samples. The results will be reported on a form 123 which will accompany the sample to the Materials Bureau.

15 "Special Borrow":

15.1 District or Area labs will determine the gradation, LL, PI and soil class for Special Borrow "R" Value samples. The results will be reported on a form 123 which will accompany the sample to the Materials Bureau.

16 Reduction of Sample Size by Quartering or Splitting:

16.1 The procedure for reducing the size of field sample of aggregate is described in MT-417.

17 Required Production Samples other than Aggregates for Plant Mix:

17.1 Field testing for Acceptance shall conform to the frequency as shown in MT-601, under "Aggregate Surfacing".

18 Independent Assurance Samples:

18.1 The District or Area laboratories shall take Independent Assurance samples in accordance with the frequency shown in MT-601. When Independent Assurance samples are taken, a sufficient quantity of material shall be obtained to make three separate samples after splitting or quartering. One of these samples will be tested in the field. The second is to be marked Independent Assurance and taken to the District or Area laboratory and the third is to be marked Independent Assurance and sent to the Materials Bureau. This procedure will make direct comparison possible between the field, District or Area laboratory and the Materials Bureau.

18.2 If discrepancies occur between the District or Area laboratory and the Acceptance samples, the District or Area laboratory will investigate and change any procedures found to be causing the differences.

18.3 If differences are found to exist between the District or Area laboratory and the Materials Bureau, the Materials Bureau will have the authority to investigate all of the testing procedures and make any changes found necessary.

19 Plant Mix Aggregates:

19.1 Sampling will be in accordance with the sample size and frequency described in MT-601 and the following:

19.2 *WHEN STOCKPILED* - In order to establish a stockpile average, the samples shall be secured and tested as the stockpile is being produced.

19.3 *BATCH TYPE HOT PLANT*- A representative sample of dried aggregate shall be provided by means of an approved sampling device.

19.4 *DRYER DRUM HOT PLANT* - A representative composite sample shall be provided, by means of an approved sampling device, at a point just prior to the aggregate entering the dryer drum mixer.

19.5 *CONTINUOUS FLOW HOT PLANT* - A representative sample of dried aggregate shall be provided by means of an approved sampling device.

20 Aggregates for Design:

20.1 **MAINTENANCE MIX DESIGN** - The amount of material submitted to the Materials Bureau for a proposed mix design shall be as follows: Plant Mix Aggregate - 300 lbs. (136 Kg), Seal and Cover Aggregate - 150 lbs. (68 Kg).

20.2 The sample shall be prepared in the district or area laboratory as described in 19.2 and 19.3.

20.3 Non-Quality Assurance Projects

20.3.1 When a satisfactory stockpile average has been established, a sieve analysis shall be performed, in the District or Area laboratory, on a representative sample of the stockpiled material.

20.3.2 Compare the sieve analysis obtained in paragraph19.2 above, to the established stockpile average.

20 Aggregates for Design: (continued)

20.3.3 If the minus 4 mesh portion of the sample is within plus or minus 2% and the minus 200 mesh portion is within plus or minus 1% of the stockpile average, the sample may be submitted to the Materials Bureau for a mix design, without further preparation.

20.3.4 If the sample does not meet the above criteria, it will be necessary to adjust the gradation, in the District or Area laboratory, to allowable variations described in paragraph 20.2.3 above, before it is shipped to the Materials Bureau.

20.3.5 The stockpile average shall be shown on the laboratory work sheet that accompanies the sample.

21.4 Quality Assurance Projects:

21.4.1 The stockpile shall be sampled according to MT-201, Section 10 - (Stockpile Samples) and then be submitted to the Materials Bureau for the mix design when sufficient quantity has been accumulated to insure a satisfactory stockpile gradation average. Gradation test results of the stockpile and the contractors Job Mix Target shall accompany the sample.

22 Mineral Filler:

22.1 One 2.3 Kg (5 lb.) sample per project of mineral filler will be sampled and submitted to the Materials Bureau for testing and acceptance.

23 Compaction Samples:

23.1 The District or Area laboratory shall run at least one sample from each different soil type using the methods described in MT-210 or MT-230. It will not be necessary to submit compaction samples to the Materials Bureau. If the material being sampled consists of fine material, 30 pounds (14 Kg) shall be obtained. If the material consists of coarse and fine material, the sample shall be large enough to yield 30 lbs. (14 Kg) of the fine material (minus 4 mesh).

24 Field Density Tests:

24.1 Field density tests shall be taken in accordance with MT-601, under "Density Control, Embankment" and MT-218 (Determining Relative Compaction and Percent Moisture).

25 Concrete Aggregates:

25.1 Concrete aggregate samples shall be submitted in accordance with MT-601.

26 Concrete Test Specimens:

26.1 Concrete compressive and flexural strength test specimens will be made and cured in accordance with MT-101.

27 Cement Treated Base:

27.1 Cement Treated Base shall be sampled in accordance with MT-216 and MT-601.

28 Field Construction Sampling:

28.1 This procedure applies to material used for cut and fill sections within the R/W limits of the project.

28.2 Samples for soil classification and "R" value shall be obtained from the top 2 feet (0.6 meters) of the sub-grade. Sample frequency will be one sample every 1000 feet (305 meters) for projects

28 Field Construction Sampling: (continued)

with 3 or more cuts or fills per mile. If the project has fewer than 3 cuts or fills per mile the sample distance is extended to 2000 feet (610 meters).

28.3 District/Area lab personnel will determine the soil classification. If the soil class is not equal to or better than that used by the Surfacing Design Unit to determine the typical section, then samples for "R" value determination are to be submitted to the Materials Bureau in Helena.

NOTE: These samples are as a design check only. Sampling every 1000 feet (305 meters) is a general guide and some discretion should be used. For example, it may be advisable to take more samples in fill sections than cut sections, or if there is an obvious change in the soil conditions or soil class, etc. No samples will be required for typical sections with a design "R" of 5 or less or for soils classified as A-6 or A-7.

METHODS OF SAMPLING AND TESTING
MT 202-04
SIEVE ANALYSIS OF FINE AND COARSE AGGREGATE
MAXIMUM SIZE THROUGH 200 MESH
(Modified AASHTO T 11 and T 27)

1 Scope:

1.1 This method covers the determination of the particle size distribution of fine and coarse aggregates by sieving.

1.2 Material Passing the 4.75 mm (no. 4) sieve will be washed. Clay particles and other aggregate particles that are dispersed by the wash water, as well as water-soluble materials, will be removed from the aggregate during testing.

2 Referenced Documents:

2.1 ***AASHTO:***
T11 Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing
T27 Sieve Analysis of Fine and Coarse Aggregates

MT Manual:
MT-201 Sampling Roadway Materials
MT-405 Wire Cloth Sieves for Testing Purposes
MT-417 Reducing Field Samples to Testing Size

3 Apparatus:

3.1 *Balance* - The scale or balance for the coarse material (plus 4 mesh) shall have a sensitivity of 0.01 pounds or 0.01 kilograms. Coarse material weights shall be recorded to the nearest 0.01 of a pound or 0/.01 kilogram. The scale or balance for the fine material (minus 4 mesh) shall have a sensitivity of 0.1 gram. Fine material weights shall be recorded to the nearest 0.1 gram.

3.2 *Sieves* - The sieves with square openings shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. Suitable sieve sizes shall be selected to furnish the information required by the specifications covering the material to be tested. The sieves shall conform to the requirements of MT-405, Wire Cloth Sieves for Testing Purposes.

3.2.1 *Sieves*--A nest of two sieves, the lower being a 75-µm (No. 200) sieve and the upper being a sieve with openings in the range of 2.36 mm (No. 8) to 1.18 mm (No. 16), both conforming to the requirement of MT 405.

3.3 *Container* - A container sufficient to contain the sample covered with water and to permit vigorous agitation without inadvertent loss of any part of the sample or water is required. The container shall be approved by the District Materials Supervisor or Area Laboratory Supervisor prior to use.

3.4 *Oven* - An oven of sufficient size, capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F) is required.

4 Preparation of Samples:

4.1 Samples for sieve analysis shall be prepared in accordance with MT-417, Reducing Field Samples to Testing Size. The samples shall be the weight desired when dry. The selection of samples of an exact predetermined weight shall not be attempted.

4.2 Dry the sample at a temperature of 110 ± 5°C (230 ± 9°F) to a constant weight. For control purposes, particularly where rapid results are desired, it is generally not necessary to dry coarse aggregate for the sieve analysis test. The results are insignificantly affected by the moisture

4 Preparation of Samples: (continued)

content unless the nominal maximum size is smaller than 12.5 mm (½ in.), or the coarse aggregate contains appreciable material finer than 4.75 mm (No. 4); or the coarse aggregate is highly absorptive (a lightweight aggregate, for example). Samples may be dried at higher temperatures associated with the use of hot plates without affecting results, provided steam escapes without generating pressures sufficient to fracture the particles, and temperatures are not so great as to cause chemical breakdown of the aggregate.

NOTE 1 - Samples taken for Liquid Limit, Plastic Limit, and Plasticity index shall be air dried or dried at a temperature no greater than 140°F or 60°C.

4.3 Samples are considered dry when complete separation of the coarse aggregate from the minus 4 mesh material is observed, and the material is dryer than SSD (Saturated Surface Dry). **NOTE: Two moisture checks per shift will be required.**

4.4 Representative samples will be graded to determine the percentage of fine material adhering to the coarser fractions. At least one sample shall be taken by field personnel at the start of production of aggregate. When material is being removed from the stockpile before production of aggregate has concluded, it is suggested that more samples be taken to insure uniform production. The District Materials Supervisor or Area Laboratory Supervisor will determine the total number and weight of samples graded. The Materials Bureau will require one sample from the material submitted for mix design.

4.5 *Fine Aggregate* - The test sample of fine aggregate shall weigh, after drying, approximately the following amount:

Aggregate with at least 95% passing a 2.36 mm (No. 8) sieve . . . 100g
Aggregate with at least 85% passing a 4.75 mm (No. 4) sieve
and more than 5% retained on a 2.36 mm (No. 8) sieve 500g

4.6 *Coarse Aggregate* - The weight of the test sample of coarse aggregate shall conform with the following minimum weights:

SPECIFIED 100% PASSING SIEVE SIZE		Min. Field Test Sample Size*	
mm	In	Kg	lbs.
*9.5	(3/8)	6.8	15
*12.5	(1/2)	6.8	15
*19.0	(3/4)	9.1	20
*25.0	(1)	11.3	25
*37.5	(1 ½)	15	33
50	(2)	20	44
63	(2 ½)	35	77

NOTE 2 - For cover material, concrete aggregate, and samples that require a wear, cleanliness value test, the sample size sent to Helena must be doubled.

4.7 *Coarse and Fine Aggregate Mixtures* - The weight of the test sample of coarse and fine aggregate mixtures shall be the same as for coarse aggregate.

5 Procedure for Clinging Fines:

5.1 Follow the procedure in Section 4 for the original test. Save the plus 4.75 mm (4 mesh) material.

5.2 Wash the plus 4.75 mm (4 mesh) material over a protected 75 μm (200 mesh) screen. In most cases it is not necessary to rewash the minus 4.75 mm (4 mesh) material. Dry and re-screen over the original sized screens. Use the original weight of sample taken for the calculation of the plus 4.75 mm (4 mesh) percentages.

5.3 Obtain the difference between the original plus 4.75 mm (4 mesh) material and the washed plus 4.75 mm (4) material. Record for use in calculations of the minus 4.75 mm (4 mesh) material. To convert from the pounds of minus 4 mesh material to grams, multiply by 453.6.

Example: (0.39 pounds) X (453.6) = 176.9 grams.

Use the percentage difference passing the 4.75 mm (4 mesh) divided by the before wash weight to get the reciprocal for multiplication.

Example: (1.55%)/176.9 g) = 0.0088

5.4 The total percent clinging fines is the difference in percent of the plus 4.75 mm (4 mesh) screen sizes.

Example: 55.61(dry) - 54.06(washed) = 1.55% (report as 1.6%)

6 Procedure for Aggregate Without Clinging Fines:

6.1 The total sample as prepared in Section 4 shall be separated into a series of sizes. To determine compliance with the specifications for the material under test, avoid overloading the screens.

6.2 *PLUS 4 MESH PORTION* - The individual weights of the air dried plus 4 mesh portion of the sample, retained on each screen, shall be determined and recorded.

6.2.1 The individual portions shall be saved until the entire plus 4.75 mm (4 mesh) portion of the sample has been screened, weighed and the weights recorded, before any of the material is discarded.

6.2.2 The total amount of material finer than the 4.75 mm (4 mesh) sieve may be determined by subtracting the total weight of material retained on the plus 4.75 mm (4 mesh) sieve from the total weight of the sample being tested.

6.3 *MINUS 4 MESH PORTION* - At the completion of the sieving as described in Section 6.2, the entire minus 4.75 mm (4 mesh) portions shall be thoroughly mixed and reduced to a minimum of 500 grams.

6.3.1 After drying and weighing, place the test sample in the container and add sufficient water to cover it. A detergent, dispersing agent, or other wetting solution may be added to the water to assure a thorough separation of the material finer than the 75 μm (No. 200) sieve from the coarser particles. Agitate the sample with sufficient vigor to result in complete separation of all particles finer than the 75 μm (No. 200) sieve from the coarser particles, and to bring the fine material into suspension. Immediately pour the wash water containing the suspended and dissolved solids over the nested sieves, arranged with the coarser sieve on top. Take care to avoid, as much as feasible, the decantation of coarser particles of the sample.

6.3.2 Add a second change of water to the sample in the container, agitate, and decant as before. Repeat the operation until the wash water is clear.

6 Procedure for Aggregate Without Clinging Fines: (continued)

6.3.3 Following the washing of the sample and flushing any materials retained on the 75 μm (No. 200) sieve back into the container, no water should be decanted from the container except through the 75 μm sieve, to avoid loss of material. Excess water from flushing should be evaporated from the sample in the drying process. The washed aggregate shall be dried to constant mass. Constant mass has been reached when there is less than a 0.1 percent change after an additional 30 minutes of drying for ovens or when close control of temperature is not required, such as hot plates, an additional 20 minutes drying.

NOTE 3 - A minimum drying time will be established and posted in the test trailer and checked periodically.

6.3.4 The individual weights of each size of the minus 4 mesh portion retained on each sieve shall be determined and recorded. Use a scale or balance conforming to the requirements specified in paragraph 3.1.

6.3.5 The individual portions shall be saved until the entire minus 4.75 mm (4 mesh) portion of the sample that was washed has been screened, weighed, and the weights recorded, before any of the material is discarded.

7 Sieving Procedure:

7.1 Nest the sieves in order of decreasing size of opening from top to bottom and place the sample on the top sieve. Agitate the sieves by hand or by mechanical apparatus for a sufficient period established by trial or checked by measurement on the actual test sample, to meet the criterion for adequacy of sieving described in Section 7.3.

7.2 Limit the quantity of material on a given sieve so that all particles have an opportunity to reach sieve openings a number of times during the sieving operation. The following table shows the maximum weight that can be retained on each individual sieve at the completion of the sieving operation. In no case shall the weight be so great as to cause permanent deformation of the sieve cloth.

MAXIMUM WEIGHT RETAINED

Screen Size	203 mm Diameter (8" Diameter) Screen Maximum Grams	203 mm Diameter (8" Diameter) Screen Maximum Pounds	304.8 mm Diameter (12" Diameter) Screen Maximum Grams	304.8 mm Diameter (12" Diameter) Screen Maximum Pounds	14 3/4" X 22 3/4" Tray Gilson Screen Maximum Grams	14 3/4" X 22 3/4" Tray Gilson Screen Maximum Pounds
31.75 mm (1 1/4")			3821.9	8.4	11339.8	25
25.0 mm (1")			3057.5	6.7	9071.8	20
19.0 mm (3/4")			2598.9	5.7	7711.0	17
16.0 mm (5/8")			2293.2	5.1	6803.9	15
12.5 mm (2")			1987.4	4.4	5896.7	13
9.5 mm (3/8")			1223.0	2.7	3628.7	8
4.75 mm (4 M)	318	0.7	917.3	2.0	2721.5	6
2.36 mm (8 M)	194	0.4	436.5	0.9	1814.1	4
2.00 mm (10 M)	194	0.4	436.5	0.9	1814.1	4
425 μm (40 M)	194	0.4	436.5	0.9		
180 μm (80 M)	194	0.4	436.5	0.9		
75 μm (200 M)	194	0.4	436.5	0.9		

7 Sieving Procedure: (continued)

7.3 Continue sieving for a sufficient period and in such manner that, after completion, not more than 0.5 percent by weight of the total sample passes any sieve during 1 min. of continuous hand sieving. Perform as follows: Hold the individual sieve, provided with a snug-fitting pan and cover, in a slightly inclined position in one hand. Strike the side of sieve sharply and with an upward motion against the heel of the other hand at the rate of about 150 times per minute, turn the sieve about one sixth of a revolution at intervals of about 25 strokes. In determining sufficiency of sieving for sizes larger than the 4.75 mm (No. 4) sieve, limit the material on the sieve to a single layer of particles. If the size of the mounted testing sieves makes the described sieving motion impractical, use 203 mm (8 in.) diameter sieves to verify the sufficiency of sieving.

7.4 The efficiency of the mechanical shaker shall be checked periodically by comparing results with the hand method. This practice will help determine the length of time required for the mechanical shaker to adequately separate material sizes.

8 Calculations:

8.1 *Plus 4.75 mm (4 Mesh) Material* - For each of the various sieves, the individual weights retained must be converted to total weight passing. The total weight passing is divided by the total weight of the sample multiplied by 100, which will result in the percent passing. (See the example on the following worksheets).)

8.2 *Minus 4.75 mm (4 Mesh) Material* - Calculating the percentages of the minus 4.75 mm (4 mesh) portion of the sample is simplified by using a reciprocal. The reciprocal is determined by dividing the percent of material passing the minus 4.75 mm (4 mesh) sieve by the weight of the minus 4.75 mm (4 mesh) sample before washing. This reciprocal, when multiplied by the various total weights passing, results in the percent passing, in relation to the total sample. (See the example on the following worksheets).

9 Report:

9.1 The results of the sieve analysis shall be reported as the total percentages passing each sieve size and reported to the nearest whole number for all material coarser than the 75 μm (200 mesh). The 75 μm (200 mesh) material shall be reported to one tenth of one percent. Percentages shall be calculated on the basis of the total weight of the sample, including any material finer than the 75 μm (200 mesh) sieve.

10 Hot Plant Mix Aggregates:

10.1 Plant mix aggregates shall be governed by the provisions of MT-202, except that sampling will be in accordance with MT-201, which provides that the samples be obtained by means of an approved sampling device.

MBA Form No. 123
3255-1300
(Rev. 3-92)

Montana Department of Transportation
Materials Bureau
2701 Prospect Ave.
Helena, MT 59620-9726

District Lab. No._____
Lab. No._____ Sample_____ Hole_____ Project_____
Termini_____
Date Sampled_____ Date Received_____ Kind of Deposit_____
Sampled by_____ Title_____ Address_____
Submitted by_____ Title_____ Date_____
Quantity_____ Area by Stationing_____
Area is in_____ Sec._____ T-_____ R-_____
Lab. No._____ County_____
Owner_____ Address_____
Sta. and/or Tons Production Sample_____ Lift No._____
Examined for 3/4" CTS A Gr. 2

Wt. of Sample Taken 11.84 Kg. 100.00 %
Wt. Retained 4-Mesh 6.40 Kg. 54.05 %
Wt. Passing 4-Mesh 5.44 Kg. 45.95 %
Before Wash 478.7 After 450.7 LBW 28.0

LL_____ PL_____ PI_____
Wear_____% Fld. Agg. Chart No._____
Fracture_____% Sp. Gr. (F)_____ (C)_____
Max. Dens._____ Soil Class_____
Opt. Moist_____ Wt./Ft.^{3}_____
Dust Ratio_____ Sand Equiv._____

Cum.wt.	Size	Wt.Pass.	Pct.	Spec.
_____	114 mm	_____	_____	_____
_____	100 mm	_____	_____	_____
_____	90 mm	_____	_____	_____
_____	75 mm	_____	_____	_____
_____	63 mm	_____	_____	_____
_____	50 mm	_____	_____	_____
_____	37.5mm	_____	_____	_____
_____	31.5mm	_____	_____	_____
_____	25 mm	11.84	100	_____
1.22	16,19mm	10.62	90	_____
3.55	12.5 mm	8.29	70	_____
5.05	9.5 mm	6.79	57	_____
6.40	4.75mm	5.44	46	_____
149.5	2.36/2.0mm	329.2	32	_____
319.1	.425 mm	159.6	15	_____
417.1	.180 mm	61.6	6	_____
450.7	.075 mm	28.0	2.7	_____

VOLUME SWELL Specimen

Age	Treat.	% Swell	Spec.Condition

ADHESION

% Adhesion	Bitumen	Adhesive Agent

CHECKED AND APPROVED Name _____
Date _____

REMARKS: PLUS 4.75 mm (4 MESH) MATERIAL - The total weight passing each sieve divided by the total weight of the sample (11.84 Kg.), multiplied by 100, results in percent passing.
EXAMPLE: 5.44 ÷ 11.84 = 0.46 X 100 = 46%

MINUS 4.75 mm (4 MESH) MATERIAL - (By reciprocal method) A reciprocal is determined by dividing the percent of material passing the 4 mesh (45.95) by the weight of the minus 4 mesh sample before washing (478.7 grams). This reciprocal (0.0960) multiplied by the various total weights passing, results in the percent passing in relation to the total sample.

Form 104 (Rev. 11/87)
3255-1150
MT270

DEPARTMENT OF TRANSPORTATION
FIELD AGGREGATE CHART

Project No. **(Sample for Clinging Fines)** Designation_____ Mat'ls. Supvr._____
County_____ Laboratory Pit No._____ Test For_____
Pit Location_____ Section_____ Township_____ Range_____

Test No._____ Lot No._____
Date_____
Sampled By_____
Tested By_____
Stationing_____
Lift_____ Lane_____

Wt.of Sample Taken 25.23 lbs. 100 %
Wt.Retained 4-Mesh 11.59 lbs. 45.9 %
Wt.Passing 4-Mesh 13.64 lbs. 54.1 %
Bef.Wash 520.5 Aft.Wash 448.0 LBW 72.5

Cum.Wt.	Size	Tot.Wt. Pass.	%
	4½"		
	4"		
	32"		
	3"		
	2½"		
	2"		
	1½"		
	1¾"		
	1"		
0	3/4"	25.23	100
1.29 lbs.	2"	23.94	94.89
4.69 lbs.	3/8"	20.54	81.41
11.59 lbs.	4 M	13.64	54.06
* 219.7 g	8/10 M	300.8	31.24
375.8 g	40 M	144.7	15.03
420.5 g	80 M	100.0	10.39
447.9 g	200 M	72.6	7.54
	Total		

*-4 Mesh Sample Split and Sieved
-4+10_____%
Dust Ratio_____%
Moisture_____%
Fracture_____%
Liquid Limit_____
Plasticity Index_____
Checked By_____ Date_____

Test No._____ Lot No._____
Date_____
Sampled By_____
Tested By_____
Stationing_____
Lift_____ Lane_____

Wt.of Orig. Sample Taken 25.23 lbs.
Difference in Weight
Passing 4-Mesh 0.39 lbs. 1.55%
Bef.Wash 176.9 Aft.Wash____ LBW_____

Cum.Wt.	Size	Tot.Wt. Pass.	%
	4½"		
	4"		
	3½"		
	3"		
	2½"		
	2"		
	1½"		
	1¾"		
	1"		
0	3/4"	25.23	100
1.22 lbs.	2"	24.01	95.16
4.43 lbs.	3/8"	20.80	82.44
11.20 lbs.	4 M	14.03	55.61
19.9 g	8/10 M	157.0	1.38
48.4 g	40 M	128.5	1.13
90.0 g	80 M	86.9	0.76
174.9 g	200 M	2.0	0.02
	Total		

-4+10_____%
Dust Ratio_____%
Moisture_____%
Fracture_____%
Liquid Limit_____
Plasticity Index_____
Entered By_____ Date_____

Test No._____ Lot No._____
Date_____
Sampled By_____
Tested By_____
Stationing_____
Lift_____ Lane_____

Wt.of Sample Taken_____ lbs.___100%
Wt.Retained 4-Mesh_____ lbs._____%
Wt. Passing 4-Mesh_____ lbs._____%
Bef.Wash____ Aft.Wash_____LBW_____

Act.Grading % Passing	Size	% Clinging Fines
	4½"	
	4"	
	3½"	
	3"	
	2½"	
	2"	
	1½"	
	1¾"	
	1"	
100	3/4"	0
95.16	2"	.27
82.44	3/8"	1.03
55.61	4 M	1.55
32.62	8/10 M	
16.16	40 M	
11.15	80 M	
7.56	200 M	
	Total	

Note: Report the Percent Clinging Fines as 1.6%
-4+10_____%
Dust Ratio_____%
Moisture_____%
Fracture_____%
Liquid Limit_____
Plasticity Index_____
Date_____

METHODS OF SAMPLING AND TESTING
MT 203-04
METHOD OF TEST FOR UNIT WEIGHT OF AGGREGATE
(Modified AASHTO T 19)

1 Scope:

1.1 This method covers the determination of unit weight in a compacted or loose condition, and calculated voids in fine, coarse, or mixed aggregates based on the same determination. The method is applicable to aggregates not exceeding 6 in. [150 mm] in nominal maximum size.

Note 1 - Unit weight is the traditional terminology used to describe the property determined by this test method. Some believe the proper term is unit mass or density or bulk density, but consensus on this alternate terminology has not been obtained.

1.2 The values stated in either inch-pound units or acceptable metric units are to be regarded separately as standard, as appropriate for a specification with which this test method is used. An exception is with regard to sieve sizes and nominal size of aggregate, in which the metric values are the standard as stated in AASHTO M 92. Within the text, metric units are shown in brackets. The values stated in each system may not be exact equivalents; therefore, each system must be used independently of the other, without combining values in any way.

2 Referenced Documents:

2.1 ***AASHTO:***
M 92 Wire Cloth and Sieves for Testing Purposes
T 2 Sampling Aggregates
T 19 Bulk Density ("Unit Weight") and Voids in Aggregate
T 84 Specific Gravity and Absorption of Fine Aggregate
T 85 Specific Gravity and Absorption of Coarse Aggregate

MT Manual:
MT-115 Weight per Cubic Foot, Yield and Air Content (Gravimetric) of Concrete
MT-204 Absorption of Fine Aggregate
MT-205 Specific Gravity and Absorption of Coarse Aggregate
MT-405 Specification for Wire-Cloth Sieves for Testing Purposes
MT-417 Procedure for Reducing Field Samples of Aggregate to Testing Size

3 Apparatus:

3.1 *Balance* - A balance or scale accurate within 0.3 percent of the test load at any point within the range of use. The range of use shall be considered to extend from the weight of the measure empty to the weight of the measure plus its contents at 100 pounds per cubic foot (1600 kilograms per cubic meter).

3.2 *Tamping Rod* - A round, straight steel rod, 3/8 in. (16 mm) in diameter and approximately 24 in. (600 mm) in length, having one end rounded to a hemispherical tip of the same diameter as the rod.

3.3 *Measure* - A cylindrical metal measure preferably provided with handles. It shall be watertight, with the top and bottom true and even, and sufficiently rigid to retain its form under rough usage. The measure should have a height approximately equal to the diameter, but in no case shall the height be less than 80% nor more than 150% of the diameter. The capacity of the measure shall conform to the limits in Table 1 for the aggregate size to be tested. The thickness of metal in the measure shall be as described in Table 2. The top rim shall be smooth and plane within 0.01 in. [0.25 mm] and shall be parallel to the bottom within 0.5° (Note 2).

TABLE 1 Capacity of Measures			
Nominal Maximal Size of Aggregate		Capacity of Measure[A]	
in.	mm	ft³	L(m³)
1/2	12.5	1/10	2.8 (0.0028)
1	25.0	1/3	9.3 (0.0093)
1½	37.5	1/2	14 (0.014)
3	75	1	28 (0.028)
4½	112	2½	70 (0.070)
6	150	3½	100 (0.100)

[A]The indicated size of measure shall be used to test aggregates of a nominal maximum size equal to or smaller than that listed. The actual volume of the measure shall be at least 95% of the nominal volume listed.

TABLE 2 Requirements of Measures			
Capacity of Measure	Thickness of Metal, min		
	Bottom	Upper 1½ in. or 38 mm of Wall[A]	Remainder of Wall
Less than 0.4 ft³	0.20 in.	0.10 in.	0.10 in.
0.4 ft³ to 1.5 ft³, incl	0.20 in.	0.20 in.	0.10 in.
Over 1.5 to 2.8 ft³, incl	0.40 in.	0.25 in.	0.10 in.
Over 2.8 to 4.0 ft³, incl	0.50 in.	0.30 in.	0.20 in.
Less than 11 L	5.0 mm	2.5 mm	2.5 mm
11 to 42 L, incl	5.0 mm	5.0 mm	3.0 mm
Over 42 to 80 L, incl	10.0 mm	6.4 mm	3.8 mm
Over 80 to 133 L, incl	10.0 mm	7.6 mm	5.0 mm

[A]The added thickness in the upper portion of the wall may be obtained by placing a reinforcing band around the top of the measure.

Note 2 - The top rim is satisfactorily plane if a 0.01 in. [0.25 mm] feeler gage cannot be inserted between the rim and a piece of ¼ in. (6 mm) or thicker plate glass laid over the measure. The top and bottom are satisfactorily parallel if the slope between pieces of plate glass in contact with the top and bottom does not exceed 0.87 percent in any direction.

3.1.1 If the measure may also be used for testing for unit weight of concrete according to T 121, the measure should be made of steel or other suitable metal not readily subject to attack by cement paste.

3 ***Apparatus:*** *(continued)*

Note 3 - Reactive materials such as aluminum alloys may be used where, as a consequence of an initial reaction, a surface film is formed which protects the metal against further corrosion. Measures larger than nominal 1-ft³ (28-L) capacity should be made of steel for rigidity, or the minimum thicknesses of metal listed in Table 2 should be suitably increased.

3.4 *Shovel or Scoop*--A shovel or scoop of convenient size for filling the measure with aggregate.

3.5 *Calibration Equipment*--A piece of plate glass, preferably at least ¼ in. [6 mm] thick and at least 1 in. [25 mm] larger than the diameter of the measure to be calibrated. A supply of water pump or chassis grease that can be placed on the rim of the container to prevent leakage.

4 Sampling:

4.1 Sampling should generally be accomplished in accordance with MT 417, Procedure for Reducing Field Samples of Aggregate toTesting Size.

5 Sample:

5.1 The size of sample shall be approximately 125 to 200% of the quantity required to fill the measure, and shall be handled in a manner to avoid segregation. Dry the sample of aggregate to essentially constant mass, preferably in an oven at 230 ± 9°F (110 ± 5°C).

6 Calibration of Measure:

6.1 Fill the measure with water at room temperature and cover with a piece of plate glass in such a way as to eliminate bubbles and excess water.

6.2 Determine the mass of water in the measure using the balance described in 5.1.

6.3 Measure the temperature of water to determine its density from Table 3, interpolating if necessary.

6.4 Calculate the volume, V, of the measure by dividing the mass of water required to fill the measure by its density. Alternately, calculate the factor for the measure (1/volume) by dividing the density of the water by the mass required to fill the measure.

TABLE 3 Density of Water

Temperature			
°F	°C	lb/ft³	kg/m³
60	15.6	62.366	999.01
65	18.3	62.336	998.54
70	21.1	62.301	997.97
(73.4)	(23.0)	(62.274)	(997.54)
75	23.9	62.261	997.32
80	26.7	62.216	996.59
85	29.4	62.166	995.83

6 ***Calibration of Measure:*** *(continued)*

Note 4 - For the calculation of unit weight, the volume of the measure in acceptable metric units should be expressed in cubic meters, or the factor as 1/m³. However, for convenience the size of the measure may be expressed in liters (equal to m³/1,000).

6.5 Measures shall be recalibrated at least once a year or whenever there is reason to question the accuracy of the calibration.

7 Selection of Procedure:

7.1 The shoveling procedure for loose unit weight shall be used only when specifically stipulated. Otherwise, the compact unit weight shall be determined by the rodding procedure for aggregates having a nominal maximum size of 1½ in. [37.5 mm] or less, or by the jigging procedure for aggregates having a nominal maximum size greater than 1½ in. [37.5 mm] and not exceeding 6 in. (150 mm).

8 Rodding Procedure:

8.1 Fill the measure one-third full and level the surface with the fingers. Rod the layer of aggregate with 25 strokes of the tamping rod evenly distributed over the surface. Fill the measure two-thirds full and again level and rod as above. Finally, fill the measure to overflowing and rod again in the manner previously mentioned. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

8.2 In rodding the first layer, do not allow the rod to strike the bottom of the measure forcibly. In rodding the second and third layers, use vigorous effort, but not more force than to cause the tamping rod to penetrate to the previous layer of aggregate.

Note 5 - In rodding the larger sizes of coarse aggregate, it may not be possible to penetrate the layer being consolidated, especially with angular aggregates. The intent of the procedure will be accomplished if vigorous effort is used.

8.3 Determine the mass of the measure plus contents, and the mass of the measure alone and record the values to the nearest 0.1 lb (0.05 kg).

9 Jigging Procedure:

9.1 Fill the measure in three approximately equal layers as described in 10.1 compacting each layer by placing the measure on a firm base, such as a cement-concrete floor, raising the opposite sides alternately about 2 in. (50 mm), and allowing the measure to drop in such a manner as to hit with a sharp, slapping blow. The aggregate particles, by this procedure, will arrange themselves in a densely compacted condition. Compact each layer by dropping the measure 50 times in the manner described, 25 times on each side. Level the surface of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

9.2 Determine the mass of the measure plus contents, and the mass of the measure alone, and record the values to the nearest 0.1 lb (0.05 kg).

10 Shoveling Procedure:

10.1 Fill the measure to overflowing by means of a shovel or scoop, discharging the aggregate from a height not to exceed 2 in. (50 mm) above the top of the measure. Exercise care to prevent, so far as possible, segregation of the particle sizes of which the sample is composed. Level the surface

10 **Shoveling Procedure:** (continued)

of the aggregate with the fingers or a straightedge in such a way that any slight projections of the larger pieces of the coarse aggregate approximately balance the larger voids in the surface below the top of the measure.

10.2 Determine the mass of the measure plus contents, and the mass of the measure alone, and record the values to the nearest 0.1 lb (0.05 kg).

11 Calculations:

11.1 *Unit Weight*--Calculate the unit weight for the rodding, jigging, or shoveling procedure as follows:

$$M = (G - T)/V \quad (1)$$

or

$$M = (G - T) \times F \quad (2)$$

where:

M = unit weight of aggregate, lb/ft³ [kg/m³]

G = mass of aggregate plus the measure, lb [kg]

T = mass of the measure, lb [kg]

V = volume of measure, ft³ [m³]

F = factor for measure, ft⁻³ [m⁻³]

11.1.1 The unit weight determined by this method is for aggregate in an ovendry condition. If the unit weight in terms of saturated-surface-dry (SSD) condition is desired, use the exact procedure in this method, and then determine the SSD unit weight by the following formula:

$$M_{SSD} = M[1 + (A/100)] \quad (3)$$

where:

M_{SSD} = unit weight in SSD condition, lb/ft³ [kg/m³]

A = absorption, %, determined in accordance with AASHTO T84 or T 85.

11.2 *Void Content*--Calculate the void content in the aggregate using the unit weight determined by either the rodding, jigging, or shoveling procedure, as follows:

$$\text{Voids, \%} = \frac{100\,[(S \times W) - M]}{S \times W} \quad (4)$$

where:

M = unit weight of aggregate, lb/ft³ [kg/m³]

S = bulk specific gravity (dry basis) as determined in accordance with AASHTO T 84 or T 85.

W = density of water, 62.3 lb/ft³ [998 kg/m³]

12 Report:

12.1 Report the results for unit weight to the nearest 1 lb/ft³ [10 kg/m³] as follows:

12.1.1 Unit weight by rodding, or

12.1.2 Unit weight by jigging, or

12.1.3 Loose unit weight.

12.2 Report the results for void content to the nearest 1% as follows:

12.2.1 Voids in aggregate compacted by rodding, % or

12.2.2 Voids in aggregate compacted by jigging, %, or

12.2.3 Voids in loose aggregate, %.

13 Reproducibility of Results:

13.1 Results by an operator using the sample and procedure check within one percent.

METHODS OF SAMPLING AND TESTING
MT 204-04
METHOD OF TEST FOR SPECIFIC GRAVITY AND ABSORPTION OF FINE AGGREGATE
(Modified AASHTO T 84)

1 Scope:

1.1 This method covers the determination of bulk and apparent specific gravity, 23/23°C 73.4/73.4°F), and absorption of fine aggregate.

1.2 This method determines (after 15 h in water) the bulk specific gravity and the apparent specific gravity as defined in MT-206, the bulk specific gravity on the basis of weight of saturated surface-dry aggregate, and the absorption as defined in MT-206.

1.3 The values stated in acceptable metric unit (SI units and units specifically approved in AASHTO R1 for use with SI units) are to be regarded as the standard.

1.4 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Referenced Documents:

2.1 ***AASHTO:***

MT-206 Definitions of Terms Relating to Density and Specific Gravity of Solids, Liquids, and Gases
R 1 Metric Practice
T 133 Density of Hydraulic Cement

MT Materials Manual:

MT-201 Sampling Roadway Materials
MT 205 Specific Gravity and Absorption of Coarse Aggregate
MT-417 Reducing Field Samples of Aggregate to Testing Size

2.2 ***ASTM Standards:***

C 125 Terminology Relating to Concrete and Concrete Aggregates
C 670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

3 Apparatus:

3.1 *Balance* - A balance having a capacity of 1 kilogram or more and sensitive to 0.1 gram or less.

3.2 *Pycnometer* - A flask or other suitable container into which the fine aggregate test sample can be readily introduced and in which the volume content can be reproduced with ± 0.1 cm^3. The volume of the container filled to mark shall be at least 50 percent greater than the space required to accommodate the test sample. A volumetric flask of 500 capacity or a fruit jar fitted with a pycnometer top is satisfactory for a 500-g test sample of most fine aggregates. A Le Chatelier flask as described in AASHTO T 133 is satisfactory for an approximately 55-g test sample.

3.3 *Mold* - A metal mold in the form of a frustum of a cone with dimensions as follows: 40 ± 3 mm inside diameter at the top, 90 ± 3 mm inside diameter at the bottom, and 75 ± 3 mm in height, with the metal having a minimum thickness of 0.8 mm.

3 **Apparatus:** (continued)

3.4 *Tamper* - A metal tamper weighing 340 ± 15 g and having a flat circular tamping face 25 ± 3 mm in diameter.

4 **Sampling:**

4.1 Sampling shall be accomplished in general accordance with MT-201.

5 **Preparation of Test Specimen:**

5.1 Obtain approximately 1000 grams of the fine aggregate from the sample using the applicable procedures described in MT-417.

5.1.1 Dry it in a suitable pan or vessel to constant weight at a temperature of 110 ± 5°C (230 ± 9°F). Allow it to cool to comfortable handling temperature, cover with water, either by immersion or by the addition of at least 6 percent moisture to the fine aggregate and permit to stand for 15 to 19 hours.

5.1.2 As an alternative to Section 5.1.1, where the absorption and specific gravity values are to be used in proportioning concrete mixtures with aggregates used in their naturally moist condition, the requirement for initial drying to constant weight may be eliminated and, if the surfaces of the particles have been kept wet, the 15-h soaking may also be eliminated.

Note 1 - Values for absorption and for specific gravity in the saturated surface-dry condition may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with Section 5.1.1.

5.2 Decant excess water with care to avoid loss of fines, spread the sample on a flat nonabsorbent surface exposed to a gently moving current of warm air, and stir frequently to secure homogeneous drying. If desired, mechanical aids such as tumbling or stirring may be employed to assist in achieving the saturated surface-dry condition. Continue this operation until the test specimen approaches a free-flowing condition. Follow the procedure in Section 5.2.1 to determine whether or not surface moisture is present on the constituent fine aggregate particles. It is intended that the first trial of the cone test will be made with some surface water in the specimen. Continue drying with constant stirring and test at frequent intervals until the test indicates that the specimen has reached a surface-dry condition. If the first trial of the surface moisture test indicates that moisture is not present on the surface, it has been dried past the saturated surface-dry condition. In this case, thoroughly mix a few milliliters of water with the fine aggregate and permit the specimen to stand in a covered container for 30 min. Then resume the process of drying and testing at frequent intervals for the onset of the surface-dry condition.

5.2.1 *Cone Test for Surface Moisture* - Hold the mold firmly on a smooth nonabsorbent surface with the large diameter down. Place a portion of the partially dried fine aggregate loosely in the mold by filling it to overflowing and heaping additional material above the top of the mold by holding it with the cupped fingers of the hand holding the mold. Lightly tamp the fine aggregate into the mold with 25 light drops of the tamper. Each drop should start about 5 mm (0.2 in.) above the top surface of the fine aggregate. Permit the tamper to fall freely under gravitational attraction on each drop. Adjust the starting height to the new surface elevation after each drop and distribute the drops over the surface. Remove loose sand from the base and lift the mold vertically. If surface moisture is still present, the fine aggregate will retain the molded shape. When the fine aggregate slumps slightly, it indicates that it has reached a surface-dry condition. Some angular fine aggregate or material with a high proportion of fines may not slump in the cone test upon reaching a surface-dry condition. This may be the case if fines become airborne upon dropping a handful of the sand from the cone test 100 to 150 mm into a surface. For these materials, the saturated surface-dry condition should be considered as the point that one side of the fine aggregate slumps slightly upon removing the mold.

5 Preparation of Test Specimen: (continued)

Note 2 - The following criteria have also been used on materials that do not readily slump:

(1) Provisional Cone Test - Fill the cone mold as described in Section 5.2.1 except only use 10 drops of the tamper. Add more fine aggregate and use 10 drops of the tamper again. Then add material two more times using 3 and 2 drops of the tamper, respectively. Level off the material even with the top of the mold, remove loose material from the base; and lift the mold vertically.

(2) Provisional Surface Test - If airborne fines are noted when the fine aggregate is such that it will not slump when it is at a moisture condition, add more moisture to the sand, and at the onset of the surface-dry condition, with the hand lightly pat approximately 100 g of the material on a flat, dry, clean, dark or dull nonabsorbent surface such as a sheet of rubber, a worn oxidized, galvanized, or steel surface, or a black-painted metal surface. After 1 to 3 s, remove the fine aggregate. If noticeable moisture shows on the test surface for more than 1 to 2 s, then surface moisture is considered to be present on the fine aggregate.

(3) Calorimetric procedures described by Kandhal and Lee, Highway Research Record No. 307, p. 44.

(4) For reaching the saturated surface-dry condition on a single size material that slumps when wet, hard-finish paper towels can be used to surface dry the material until the point is just reached where the paper towel does not appear to be picking up moisture from the surfaces of the fine aggregate particles.

6 Procedure:

6.1 Make and record all weight determinations to 0.1 g.

6.2 Partially fill the pycnometer with water. Immediately introduce into the pycnometer 500 ± 10 g of saturated surface-dry fine aggregate prepared as described in Section 6, and fill with additional water to approximately 90 percent of capacity. Roll, invert, and agitate the pycnometer to eliminate all air bubbles. Adjust its temperature to 23 ± 1.7°C (73.4 ± 3°F), if necessary by immersion in circulating water, and bring the water level in the pycnometer to its calibrated capacity. Determine total weight of the pycnometer, specimen, and water.

Note 3 - It normally takes about 15 to 20 minutes to eliminate air bubbles. Dipping the tip of a paper towel into the pycnometer has been found to be useful in dispersing the foam that sometimes builds up when eliminating the air bubbles.

6.2.1 *Alternative to Weighing in Section 6.2* - The quantity of added water necessary to fill the pycnometer at the required temperature may be determined volumetrically using a buret accurate to 0.15 mL. Compute the total weight of the pycnometer, specimen, and water as follows:

$C = 0.9975V_a + S + W$

where:

C = weight of pycnometer with specimen and water to calibration mark, g,

V_a = volume of water added to pycnometer, mL

S = weight of saturated surface-dry specimen, g, and

W = weight of the pycnometer empty, g.

6 Procedure: (continued)

6.2.2 *Alternative to the Procedure in Section 6.2* - Use a Le Chatelier flask initially filled with water to a point on the stem between the 0 and the 1 -mL mark. Record this initial reading with the flask and contents within the temperature range of 23 ± 1.7°C (73.4 ± 3°F). Add 55 ± 5 g of fine aggregate in the saturated surface-dry condition (or other weight as necessary to result in raising the water level to some point on the upper series of graduation). After all fine aggregate has been introduced, place the stopper in the flask and roll the flask in an inclined position, or gently whirl it in a horizontal circle so as to dislodge all entrapped air, continuing until no further bubbles rise to the surface. Take a final reading with the flask and contents within 1°C (1.8°F) of the original temperature.

6.3 Remove the fine aggregate from the pycnometer, dry to constant weight at a temperature of 110 ± 5°C (230 ± 9°F), cool in air at room temperature for 1 ± ½ h, and weigh.

6.3.1 If the Le Chatelier flask method is used, a separate sample portion is needed for the determination of absorption. Weigh a separate 500 ± 10 g portion of the saturated surface-dry fine aggregate, dry to constant weight, and reweigh.

Note 4 - In lieu of weighing the sample that has been removed from the pycnometer, a second 500 ± 10 g portion of the saturated surface dry sample may be used to determine the dry weight.

6.4 Determine the weight of the pycnometer filled to its calibration capacity with water at 23 ± 1.7°C (73.4 ± 3°F).

6.4.1 *Alternative to Weighing in Section 6.4* - The quantity of water necessary to fill the empty pycnometer at the required temperature may be determined volumetrically using a buret accurate to 0.15 mL. Calculate the weight of the pycnometer filled with water as follows:

$$B = 0.9975\ V + W$$

where:

B = weight of flask filled with water, g,

V = volume of flask, mL, and

W = weight of the flask empty, g.

7 Bulk Specific Gravity:

7.1 Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), as defined in MT-206 as follows:

$$\text{Bulk sp gr} = A/(B + S - C)$$

where:

A = weight of oven-dry specimen in air, g,

B = weight of pycnometer filled with water, g,

C = weight of pycnometer with specimen and water to calibration mark, g, and

S = weight of saturated surface-dry specimen, g.

7.1.1 If the Le Chatelier flask method was used, calculate the bulk specific gravity, 23/23°C, as follows:

$$\text{Bulk sp gr} = \frac{S_1(A/S)}{0.9975(R_2 - R_1)}$$

where:

R_1 = initial reading of water level in Le Chatelier flask,

R_2 = final reading of water level in Le Chatelier flask, and

S_1 = weight of saturated surface-dry specimen used in Le Chatelier flask, g.

8 Bulk Specific Gravity (Saturated Surface-Dry Basis):

8.1 Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), on the basis of weight of saturated surface-dry aggregate as follows:

Bulk sp gr (saturated surface-dry basis) = *A/(B+S-C)*

8.1.1 If the Le Chatelier flask method was used, calculate the bulk specific gravity, 23/23°C, on the basis of saturated surface-dry aggregate as follows:

$$\text{Bulk sp gr (saturated surface-dry basis)} = \frac{S_1}{0.9975(R_2 - R_1)}$$

9 Apparent Specific Gravity:

9.1 Calculate the apparent specific gravity, 23/23°C (73.4/73.4°F), as defined in MT-206 as follows:

Apparent sp gr = *A/(B+A-C)*

10 Absorption:

10.1 Calculate the percentage of absorption, as defined in ASTM C 125, as follows:

Absorption, % = *[(S-A)/A] x 100*

11 Report:

11.1 Report specific gravity results to the nearest 0.01 and absorption to the nearest 0.1 percent. The Appendix gives mathematical interrelationships among the three types of specific gravities and absorption. These may be useful in checking the consistency of reported data or calculating a value that was not reported by using other reported data.

11.2 If the fine aggregate was tested in a naturally moist condition other than the oven dried and 15-h soaked condition, report the source of the sample and the procedures used to prevent drying prior to testing.

METHODS OF SAMPLING AND TESTING
MT 205-04
METHOD OF TEST FOR SPECIFIC GRAVITY AND ABSORPTION OF COARSE AGGREGATES
(Modified AASHTO T 85)

1 Scope:

1.1 This method covers the determination of specific gravity and absorption of coarse aggregate. The specific gravity may be expressed as bulk specific gravity, bulk specific gravity (saturated-surface-dry (SSD)), or apparent specific gravity. The bulk specific gravity (SSD) and absorption are based on aggregate after 15 h soaking in water. This method is not intended to be used with lightweight aggregates.

1.2 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Referenced Documents:

2.1 ***AASHTO:***
M 43 Sizes of Aggregate for Road and Bridge Construction
M 92 Wire Cloth Sieves for Testing Purposes
R 1 Metric Practice

MT Materials Manual:
MT-201 Sampling Roadway Materials
MT-202 Sieve Analysis of Fine and Coarse Aggregates
MT-204 Specific Gravity and Absorption of Fine Aggregate
MT-206 Terms Relating to Density and Specific Gravity of Solids, Liquids and Gases
MT-417 Reducing Field Samples of Aggregate to Testing Size

[1]This method agrees with ASTM C 127-88 except for differences in soaking time, accuracy of weighing, balance requirements, and water tank requirements.

2.2 ***ASTM Standards:***
C 125 Terminology Relating to Concrete and Concrete Aggregates
C 670 Practice of Preparing Precision Statements for Test Methods for Construction Materials

3 Summary of Method:

3.1 A sample of aggregate is immersed in water for approximately 15 h to essentially fill the pores. It is then removed from the water, the water dried from the surface of the particles, and weighed. Subsequently the sample is weighed while submerged in water. Finally the sample is oven-dried and weighed a third time. Using the weights thus obtained and formulas in the method, it is possible to calculate three types of specific gravity and absorption.

4 Terminology:

4.1 ***Definitions:***

4.1.1 *Absorption* - The increase in the weight of aggregate due to water in the pores of the material, but not including water adhering to the outside surface of the particles, expressed as a percentage of the dry weight. The aggregate is considered "dry" when it has been maintained at a temperature of 110 ± 5°C for sufficient time to remove all uncombined water.

4.1 ***Definitions:*** (continued)

4.1.2 *Specific Gravity* - The ratio of the mass (or weight in air) of a unit volume of a material to the mass of the same volume of water at stated temperatures. Values are dimensionless.

4.1.2.1 *Apparent Specific Gravity* - The ratio of the weight in air of a unit volume of the impermeable portion of aggregate at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

4.1.2.2 *Bulk Specific Gravity* - The ratio of the weight in air of a unit volume of aggregate (including the permeable and impermeable voids in the particles, but not including the voids between particles) at a stated temperature to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

4.1.2.3 *Bulk Specific Gravity (SSD)* - The ratio of the weight in air of a unit volume of aggregate, including the weight of water within the voids filled to the extent achieved by submerging in water for approximately 15 h (but not including the voids between particles) at a stated temperature, compared to the weight in air of an equal volume of gas-free distilled water at a stated temperature.

Note 1 - The terminology for specific gravity is based on terms in MT-206 and that for absorption is based on that term in ASTM C 125.

5 Apparatus:

5.1 *Balance* - A balance having a capacity of 1 kilogram or more and sensitive to 0.1 gram or less.

5.2 *Sample Container* - A wire basket of 3.35 mm (No. 6) or finer mesh, or a bucket of approximately equal breadth and height, with a capacity of 4 to 7 L for 37.5-mm (1½-in.) nominal maximum size aggregate or smaller, and a larger container as needed for testing larger maximum size aggregate. The container shall be constructed so as to prevent trapping air when the container is submerged.

5.3 *Water Tank* - A watertight tank into which the sample and container are placed for complete immersion while suspended below the balance, equipped with an overflow outlet for maintaining a constant water level.

5.4 *Sieves* - A 4.75 mm (No. 4) sieve or other sizes as needed (see Sections 6.2, 6.3, and 6.4), conforming to M 92.

5.5 *Suspended Apparatus* - Wire suspending the container shall be of the smallest practical size to minimize any possible effects of a variable immersed length.

6 Sampling:

6.1 Sample the aggregate in accordance with MT-201.

6.2 Thoroughly mix the sample of aggregate and reduce it to the approximate quantity needed using the applicable procedures in MT-417. Reject all material passing a 4.75 mm (No. 4) sieve by dry sieving and thoroughly washing to remove dust or other coatings from the surface. If the coarse aggregate contains a substantial quantity of material finer than the 4.75 mm sieve (such as for Size No. 8 and 9 aggregates in M 43), use the 2.36 mm (No. 8) sieve in place of the 4.75 mm sieve. Alternatively, separate the material finer than the 4.75 mm sieve and test the finer material according to MT-204.

6 Sampling: (continued)

6.3 The minimum weight of test sample to be used is given below. In many instances it may be desirable to test a coarse aggregate in several separate size fractions; and if the sample contains more than 15% retained on the 37.5 mm (1½-in.) sieve, test the material larger than 37.5 mm in one or more size fractions separately from the smaller size fractions. When an aggregate is tested in separate size fractions, the minimum weight of test sample for each fraction shall be the difference between the weights prescribed for the maximum and minimum sizes of the fraction.

Nominal Maximum Size, mm (in.)	Minimum Weight of Test Sample, kg (lb.)
12.5 (½) or less	2 (4.4)
19.0 (¾)	3 (6.6)
25.0 (1)	4 (8.8)
37.5 (1½)	5 (11)
50 (2)	8 (18)
63 (2½)	12 (26)
75 (3)	18 (40)
90 (3½)	25 (55)
100 (4)	40 (88)
112 (4½)	50 (110)
125 (5)	75 (165)
150 (6)	125 (276)

6.4 If the sample is tested in two or more size fractions, determine the grading of the sample in accordance with MT-202, including the sieves used for separating the size fractions for the determinations in this method. In calculating the percentage of material in each size fraction, ignore the quantity of material finer than the 4.75 mm (No. 4) sieve or 2.36 mm (No. 8) sieve when that sieve is used in accordance with Section 6.2.

7 Procedure:

7.1 Dry the test sample to constant weight at a temperature of 110 ± 5°C (230 ± 9°F), cool in air at room temperature for 1 to 3 h for test samples of 37.5 mm (1½-in.) nominal maximum size, or longer for larger sizes until the aggregate has cooled to a temperature that is comfortable to handle (approximately 50°C). Subsequently immerse the aggregate in water at room temperature for a period of 15 to 19 hours.

Note 2 - When testing coarse aggregate of large nominal maximum size requiring large test samples, it may be more convenient to perform the test on two or more sub-samples, and the values obtained combined for the computation described in Section 8.

7.2 Where the absorption and specific gravity values are to be used in proportioning concrete mixtures in which the aggregates will be in their naturally moist condition, the requirement for initial drying to constant weight may be eliminated, and, if the surfaces of the particles in the sample have been kept continuously wet until test, the 15-h soaking may also be eliminated.

Note 3 - Values for absorption and bulk specific gravity (SSD) may be significantly higher for aggregate not oven dried before soaking than for the same aggregate treated in accordance with Section 7.1. This is especially true of particles larger than 75 mm (3 in.) since the water may not be able to penetrate the pores to the center of the particle in the prescribed soaking period.

7.3 Remove the test sample from the water and roll it in a large absorbent cloth until all visible films of water are removed. Wipe the larger particles individually. A moving stream of air may be used to assist in the drying operation. Take care to avoid evaporation of water from aggregate pores during the operation of surface-drying. Weigh the test sample in the saturated surface-dry

7 **Procedure:** (continued)

condition. Record this and all subsequent weight to the nearest 1.0 g or 0.1% of the sample weight, whichever is greater.

7.4 After weighing, immediately place the saturated-surface-dry test sample in the sample container and determine its weight in water at 23 ± 1.7°C (73.4 ± 3°F), having a density of 997 ± 2 kg/m³. Take care to remove all entrapped air before weighing by shaking the container while immersed.

Note 4 - The container should be immersed to a depth sufficient to cover it and the test sample during weighing. Wire suspending the container should be of the smallest practical size to minimize any possible effects of a variable immersed length.

7.5 Dry the test sample to constant weight at a temperature of 110 ± 5°C (230 ± 9°F), cool in air at room temperature 1 to 3 h, or until the aggregate has cooled to a temperature that is comfortable to handle (approximately 50°C), and weigh. Use this weight for A in the calculations in section 8.

8 **Calculations:**

8.1 ***Specific Gravity:***

8.1.1 *Bulk Specific Gravity*--Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), as follows:

Bulk sp gr = $A/(B - C)$

where:

A = weight of oven-dry test sample in air, g,

B = weight of saturated-surface-dry test sample in air, g, and

C = weight of saturated test sample in water, g.

8.1.2 *Bulk Specific Gravity (Saturated-Surface-Dry)* - Calculate the bulk specific gravity, 23/23°C (73.4/73.4°F), on the basis of weight of saturated-surface-dry aggregate as follows:

Bulk sp gr (saturated-surface-dry) = $B/(B - C)$

8.1.3 *Apparent Specific Gravity* - Calculate the apparent specific gravity, 23/23°C (73.4/73.4°F), as follows:

Apparent sp gr = $A/(A - C)$

8.2 *Average Specific Gravity Values* - When the sample is tested in separate size fractions, the average value for bulk specific gravity, bulk specific gravity (SSD), or apparent specific gravity can be computed as the weighted average of the values as computed in accordance with Section 8.1 using the following equation:

$$G = \frac{1}{\frac{P_1}{100\ G_1} + \frac{P_2}{100\ G_2} \ldots + \frac{P_n}{100\ G_n}}$$

where:

G = average specific gravity. All forms of expression of specific gravity can be averaged in this manner.

8 Calculations: (continued)

G_1, G_2...G_n = appropriate specific gravity values for each size fraction depending on the type of specific gravity being averaged.

P_1,P_2...P_n = weight percentages of each size fraction present in the original sample.

Note 5 - Some users of this method may wish to express the results in terms of density. Density may be determined by multiplying the bulk specific gravity, bulk specific gravity (SSD), or apparent specific gravity by the weight of water (997.5 kg/m³ or 62.27 lb ft³ at 23 °C). Some authorities recommend using the density of water at 4 °C (1.000 kg/m³ or 1.000 Mg/m³ 3 or 62.43 lb/ft³) as being sufficiently accurate. Results should be expressed to three significant figures. The density terminology corresponding to bulk specific gravity, bulk specific gravity (SSD), and apparent specific gravity has not been standardized.

8.3 *Absorption* - Calculate the percentage of absorption, as follows:

Absorption, % = [(*B* - *A*)/*A*] X 100

8.4 *Average Absorption Value* - When the sample is tested in separate size fractions, the average absorption value is the average of the values as computed in Section 8.3, weighted in proportion to the weight percentages of the size fractions in the original sample as follows:

$A = (P_1A_1/100) + (P_2A_2/100) + \ldots (P_nA_n/100)$

where:

A = average absorption, %.

A_1, A_2 ... A_n = absorption percentages for each size fraction, and

P_1, P_2 ... P_n = weight percentages of each size fraction present in the original sample.

9 Report:

9.1 Report specific gravity results to the nearest 0.01, and indicate the type of specific gravity, whether bulk (saturated-surface-dry), or apparent.

9.2 Report absorption result to the nearest 0.1%.

9.3 If the specific gravity and absorption values were determined without first drying the aggregate, as permitted in Section 7.2, it shall be noted in the report.

10 Precision and Bias:

10.1 The estimates of precision of this test method listed in Table 1 are based on results from the AASHTO Materials Reference Laboratory Reference Sample Program, with testing conducted by this test method and ASTM C 127. The significant difference between the methods is that ASTM C 127 requires a saturation period of 24 ± 4 h, while MT-205 requires a saturation period of 15 h minimum. This difference has been found to have significant effect on the precision indices. The data are based on the analyses of more than 100 paired test results from 40 to 100 laboratories.

TABLE 1 Precision

	Standard Deviation (1S)[A]	Acceptable Range of Two Results (D2S)[A]
Single operator precision:		
Bulk specific gravity (dry)	0.009	0.025
Bulk specific gravity (SSD)	0.007	0.020
Apparent specific gravity	0.007	0.020
Absorption[B], %	0.088	0.25
Multilaboratory precision:		
Bulk specific gravity (SSD)	0.011	0.32
Apparent specific gravity	0.011	0.032
Absorption[B], %	0.145	0.41

[A] These numbers represent, respectively, the (1S) and (D2S) limits as described in ASTM C 670. The precision estimates were obtained from the analysis of combined AASHTO Materials Reference Laboratory reference sample data from laboratories using 15-h minimum saturation times and other laboratories using 24 ± 4-h saturation time. Testing was performed on normal weight aggregates, and started with aggregates in the oven-dry condition.

[B] Precision estimates are based on aggregates with absorptions of less than 2%.

METHODS OF SAMPLING AND TESTING
MT 206-04
TERMS RELATING TO DENSITY AND SPECIFIC GRAVITY OF SOLIDS, LIQUIDS, AND GASES
(Modified AASHTO 132)

1 Introduction:

1.1 Attention is called to the Appendix for information concerning the definitions that follow. Their meanings and their relationships to scientific terms are briefly explained. Some standards in which they are used are compared with standards in which other definitions have been applied.

1.1.1 **Density** (of solids and liquids)--The mass of a unit volume of a material at a specified temperature. The units shall be stated, such as grams per milliliter, grams per cubic centimeter, pounds per cubic foot, or other. If the material is a solid, the volume shall be that of the impermeable portion. The form of expression shall be:

Density at *x* . . . .

where *x* is the temperature of the material.

1.1.2 **Density** (of gases)--The mass of a unit volume of a gas at a stated temperature and pressure. The units shall be stated. The form of expression shall be:

Density at *x, y* . . . .

where:

x = temperature of the gas; and

y = pressure of the gas.

1.1.3 **Density, Apparent** (of solids and liquids)--The weight in air of a unit volume of a material at a specified temperature. The units shall be stated. If the material is a solid, the volume shall be that of the impermeable portion. The form of expression shall be:

Apparent density at *x* . . . .

where *x* is the temperature of the material.

1.1.4 **Density, Bulk** (of solids)--The weight in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature. The unit shall be stated. The form of expression shall be:

Bulk density at *x* . . . .

where *x* is the temperature of the material

Note 1 - The accuracy of bulk density determinations is so low that corrections for air buoyancy and variations in the value for the acceleration of gravity are not warranted. Hence, this definition is based on weights in air.

1 **Introduction:** (continued)

1.1.5 **Specific Gravity** (of solids and liquids)--The ratio of the mass of a unit volume of a material at a stated temperature to the mass of the same volume of gas-free distilled water at a stated temperature. If the material is a solid, the volume shall be that of the impermeable portion. The form of expression shall be:

Specific gravity *x*/*y*°C . . . .

where:

x = temperature of the material, and

y = temperature of the water.

Note 2 - The term "relative density" with the same meaning as specific gravity is becoming more widely used.

1.1.6 **Specific Gravity** (of gases) - the ratio of the density of a gas, under the observed conditions of temperature and pressure, to the density of dry air of normal carbon dioxide content, at the same temperature and pressure. The units shall be stated. The form of expression shall be:

Apparent specific gravity *x*/*y*

where:

x = temperature of the gas, and

y = pressure of the gas.

1.1.7 **Specific Gravity, Apparent** (of solids and liquids)--the ratio of the weight in air of a unit volume of a material at a stated temperature to the weight in air of equal density of an equal volume of gas-free distilled water at a stated temperature. If the material is a solid, the volume shall be that of the impermeable portion. The form of expression shall be:

Apparent specific gravity *x*/*y*°C

where:

x = temperature of the material, and

y = temperature of the water.

1.1.8 **Specific gravity, Bulk** (of solids)--the ratio of the weight in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the weight in air of equal density of an equal volume of gas-free distilled water at a stated temperature. The form of expression shall be:

Bulk specific gravity *x*/*y*°C

where:

x = temperature of the material, and

y = temperature of the water.

2 Appendix:

2.1 Discussion of Definitions and Relationship to Scientific Terms

2.1.1 In scientific terminology, mass is a measure of the quantity of material in a body, and is constant regardless of geographical location, altitude, or atmospheric conditions, so long as no material is added or taken away. Weight is the force with which a body is attracted to the earth and varies from place to place with the acceleration of gravity.

2.1.2 When an equal-arm balance is used to compare an object with standards of mass ("weights"), the effects of variations in the acceleration of gravity are self-eliminating and need not be taken into account, but the apparent mass of the object is slightly different from the true mass because of the buoyant effects of the surrounding air. Mass can then be computed from apparent mass by applying a correction for air buoyancy. When a spring balance is used, an additional correction accounting for the local value of the acceleration of gravity is required for the computation of mass.

2.1.3 For many commercial and industrial processes the rigorous scientific distinction between mass, apparent mass, and weight is of no practical consequence and is therefore ignored. The term "weight" in general practice has been accepted as being the value secured when an object is weighed in air. This "weight" or "weight in air" is often converted to "weight in vacuo" by the application of an air buoyancy correction, and is then considered as synonymous with mass.

2.1.4 All of the definitions listed above are based on either "mass" or "weight in air," the distinction being that air buoyancy corrections have been applied in the former case and not in the latter. Density and specific gravity are based on mass, and should be similarly constant. Apparent density, bulk density, apparent specific gravity, and bulk specific gravity are based on weight in air, and therefore are subject to change with atmospheric conditions, locality, and altitude. These changes may be negligible, depending upon the accuracy required for the particular application.

2.1.5 The definitions are intended as a guide for future standardization of terminology relating to density and specific gravity. They do not represent the terminology presently used in many existing AASHTO and ASTM standards, which has become diversified to an undesirable extent by the variety of materials, procedures, and trade practices involved.

2.1.6 Specific gravity definitions refer to the weight of a unit volume of the sample compared with the weight of a unit volume of water.

2.1.7 The definition of bulk density, like the previous definition of bulk specific gravity, specifies that the volume shall include both permeable and impermeable voids normal to the material. This requirement for the inclusion of all voids is completely satisfied whether the volume is computed from the measured dimensions of a solid, or whether it is found by placing the material in a container of predetermined capacity. It would be expected that all standards using either of the two methods would identify the results in like terms.

2.1.8 The terms "permeable" and "impermeable" cannot be rigidly defined for general application. The exact meaning in a particular application is the conventional one inferred by the procedure specified for determining the density or specific gravity of the material in question. In AASHTO T 84 and T 85, the spaces between grains or particles of granular aggregates are not included in the permeable voids mentioned in the definition for bulk specific gravity. On the other hand, in AASHTO T 166, the method of test is designed to include in the permeable voids the spaces between particles or substances in compacted bituminous paving mixtures or other bonded or cemented mixtures.

METHODS OF SAMPLING AND TESTING
MT 207-04
CENTERLINE SOIL SURVEY

1 Introduction:

1.1 A centerline soil survey is an essential part of preliminary highway engineering. Information on the engineering properties and distribution of soils, rock and groundwater must be obtained before a reasonable and economic highway design can be developed. A soil survey is not intended to take the place of a thorough Geotechnical Foundation investigation.

1.2 The soil survey work depends on many factors which include scope of the proposed project, types and variability of materials found on the project, groundwater conditions, adverse geologic features, etc. Often field conditions found during the soil survey will increase or decrease the amount of work needed to supply the necessary information for design. The soil survey and the geotechnical investigation must be coordinated in order to preclude duplication of effort.

2 Referenced Documents:

2.1 ***AASHTO:***
T 190 Resistance R-Value and Expansion Pressure of Compacted Soils

MT Manual:
MT-210 Moisture-Density Relations of Soils Using a 5.5 lb. Rammer
MT-214 The Classification of Soil and Soil-Aggregate Mixtures
MT-230 Moisture-Density Relations of Soils Using a 10 lb. Rammer

2 Apparatus:

2.1 Equipment required to perform a soil survey may include but is not limited to the following items:

2.1.1 *Sampling tools:*
Hand shovels, picks, etc.
Hand augers, post hole diggers
Power augers and drills, etc.
Backhoes

2.1.2 *Instruments:*
Survey equipment
Nuclear moisture and density testing device
Camera & film

2.1.3 *Miscellaneous:*
Stakes and lath
Sample bags (17"X28" canvas 75 lb. capacity cloth)
Sealed containers (jars or plastic bags)
Field notebooks and forms

3 General Procedure:

3.1 General Procedure: Following is the general procedure which should be followed in conducting any soil survey. The complexity of the soil survey will depend upon many factors as discussed in 1.2 above.

3 **Procedure:** (continued)

3.2 *Reconnaissance:* reconnaissance of the proposed project should be conducted with pertinent existing information in hand. Additional information available may include but is not limited to the following items:

Maintenance records
Construction records
Topographic & geologic maps
Historic use of the area
U.S. Department of Agriculture Soil Conservation Service
County soil survey reports
Utility company maps & locations
City and county plat maps
City, county and state health department information
Information from landowners and businesses
Aerial photography

3.3 Preliminary Survey Plan:

3.3.1 A preliminary plan should be determined prior to fieldwork. This should be based upon available information and intended scope. Approximate sample site locations should be determined to enable proper soil profile determination and adequate sampling. This plan will likely change as information is gained during the actual construction of the test sites.

3.3.2 Boring records should be kept in a systematic manner and referred to new centerline stationing and elevations for each project. Such records should include and be recorded on Lab Forms 30 and 111.

Describe each site or area investigated, with each test hole, boring, or test pit clearly located (horizontally and vertically) with reference to some established coordinate system or permanent monument.

Log each test hole, boring, test pit, or cut-surface exposure with the field description and location of each material encountered clearly shown by Montana Department of Highways' symbols and word descriptions used on Form 30.

Note - Color photographs of samples, and exposed strata may be of considerable value to the Department. Each photograph should include a date and an identifying number or symbol.

Identify all soils based on MT-214 Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purpose.

Record seepage and water-bearing zones and free water-table depth found in each test hole, boring or test pit.

Identify artifacts and items of cultural and historical significance.

Note items concerning environmental hazards or other worthy notes.

3.3.3 Identify vertical and/or horizontal change of original ground where instability problems exist (landslides, subsidence, etc.).

3.4 Soil Profile Determination and Sampling:

3.4.1 Boring or test pits should be taken for laboratory analysis from all areas which may supply appreciable quantities of earthwork, and known borrow areas. Embankment areas should be tested for areas of swamp conditions or loosely compacted soils that will result in embankment settlements. The spacing of these investigations will depend upon the geologic complexity of the project area and upon the importance of soil and rock parameters to the project design. The depth should be a minimum of five feet below the proposed top of subgrade elevation or to borrow area depth.

3.5 Sampling:

3.5.1 Accurately identify each sample with the project identification, location, date, test site number and depth below reference ground surface from which it was taken. Place identification inside the container, securely close the container, protect it to withstand rough handling, and mark it with proper identification on the outside of the container. Keep samples for natural moisture determination in sealed containers to prevent moisture loss. When drying of samples may affect classification or engineering properties, protect them to minimize moisture loss.

3.5.2 Soil and water samples should be taken from the probable, proposed, or existing centerline of pipe, channel bottom and bridge locations as well as probable borrow areas, to determine pH, resistivity and sulfate (SO_4) content of the soil and water. In areas of bad soils (resistivity less than 500), additional samples should be taken.

Sample Size . . . not less than 5 lbs. (2.3 Kg.)

Sample Size, Water . . 1 quart.

3.5.3 Evaluate performance of existing installations in the immediate vicinity of the proposed site, relative to their historical performance and environmental impact. Photos of relevant installations properly labeled are helpful.

3.5.4 Representative disturbed samples for laboratory classification tests of soil, rock, and local construction material should be supplemented by undisturbed specimens.

3.5.5 Standard traffic control is required while working on the PTW.

3.6 Testing:

3.6.1 Testing analysis should be performed on all samples for the following items and recorded on Form 111.
Soil class by MT-214
Liquid limit
Plastic limit
Percent of material passing the 10 mesh, 40 mesh, and 200 mesh sieve size.
Maximum dry density and optimum moisture content by MT-230 for A-1 soils, MT 210 for all other soils
In-place density and moisture content
"R" value by AASHTO T190, all soils except A-6 and A-7's.
Depth to water table

4 Field Procedure:

4.1 Overlay, New and Reconstruction Projects:

Survey data required for all projects is as follows:

4 Field Procedure: (continued)

The PTW should be cored at least 5' into the subgrade and sampled in the driving lanes (not the shoulder) as frequently as necessary.

Typical sampling frequency is one per 1/2 mile, more or less as conditions dictate.

Note and log the mat thickness.

Note and log base thickness and subgrade. Sample and determine moisture content, record soil class (MT-214), moisture, density and "R" value (AASHTO T190).

Perform a culvert inspection, take chemical corrosion samples where necessary. Take photos at locations of bad pipe.

Review the existing project and record its past performance. A narrative summary should be provided with the soil survey.

Problem areas must be shown and recommendations for sub-excavation and the proposed depth of sub-excavation should be noted.

Anticipated borrow material should be sampled and tested for R values and corrosion.

Projects, where the intent is to overlay the existing plant mix, should be cored and the cores submitted to the Materials Bureau for evaluation. A typical sampling frequency is one (1) core per lane mile with a minimum of five (5) cores per project. The frequency can and should be adjusted as conditions warrant. The cores will be evaluated to determine the in-place condition of the PMS and a report issued to Surfacing Design.

4.2 New and Reconstruction Projects Only:

Additional survey data for new and reconstruction projects only are as follows:

Review planning reports and anticipate alignment and grades.

Test holes in the field should be located to provide engineering soil properties where appreciable quantities of excavation will occur. Depth will be determined by the new grade line with holes extending about five feet below the proposed subgrade line. Typical sampling frequency is one per 1/2 mile, more or less as conditions dictate.

Tests should include samples of each soil strata encountered and the in place moisture, the chemical-corrosive properties, soil class (MT-214), "R" value (AASHTO T190), and the specific gravity for each strata.

Determine in place densities for shrink and swell determinations if frozen conditions do not exist.

A log of the test holes should be kept and the test holes plotted on a profile sheet.

Data obtained should be reviewed to determine if additional test sites (i.e., areas of refusal, inadequate depth, or of questionable frequencies) are required.

Topsoil depth and availability should be noted.

Any anticipated borrow material should be sampled for "R" value, chemical-corrosive properties, and moisture density purposes.

4.2 New and Reconstruction Projects Only: (continued)

If centerline is following close to the PTW and material in present embankment will be used, additional R-values and chemical-corrosive properties should be taken beneath the PTW driving lanes.

Potential borrow areas that have better quality soils (A-4(0) or better) should be investigated to determine their use in the top 2' of the subgrade especially in areas where surfacing materials are scarce.

5 Interpretation of Results:

5.1 Interpret the results of an investigation only in terms of actual findings and make every effort to collect and include all field and laboratory data from previous investigations in the same areas. Extrapolation of data into local areas not surveyed and tested can be done only where geologically uniform subsurface conditions of soil and rock are known to exist. Engineering properties of the soils and rocks encountered on important projects should not be predicted wholly on field identifications or classification but should be checked by laboratory and field tests made on samples collected.

5.2 The recommendations for design parameters can be made only by professionals who have specialized in the field of soils and foundations or highway engineering, and who are familiar with the problems for which the study is being made.

6 Report:

6.1 A soil survey investigation report should:

6.1.1 Locate the area investigated in terms pertinent to the project. This may include sketch maps or aerial photos on which the test holes, pits, and sample areas are located, as well as topographic items relevant to the determination of the various soil and rock types, such as contours, streambeds, sink holes, cliffs, etc. Where feasible, include a geologic map of the area investigated in the report.

6.1.2 Include copies of all borings, test-hole logs and laboratory test results.

6.1.3 Describe and relate the findings obtained by following the format of Section 3, General Procedure.

6.1.4 Provide preliminary shrink/swell recommendations. Shrink/swell information obtained from adjacent projects in the area should be included.

6.1.5 Provide recommendations relative to availability of better quality soils (A-4(0) or better) that could be used in the top 2' of the subgrade to reduce more costly surfacing material and to improve drainage.

Provide recommendations for additional testing required by core drill, seismic, etc., for materials inaccessible because of depth, topography, etc.

6.1.6 Each soil survey shall be submitted and distributed as follows:

1 copy to Preconstruction Bureau
1 copy to Geotechnical & Materials Bureau
1 copy to Surfacing Design - Materials Bureau
2 copies to be retained by the District

DRAINAGE EVALUATION FORM
MT 207

This form should be submitted with each soil survey. Each area of concern on the project should be noted.

Project No._____ Designation:_____

Date_____ Submitted by:_____

Station(s)_____

Are the ditch lines clear of standing water? _____

_____

Are the ditch lines and pavement edges free from weed growth that may indicate a moisture concentration? _____

_____

After a rain,

a) Is there moisture standing in the joints or cracks?_____

b) Is there any evidence of pumping?_____

c) Is there water standing at the outer edge of the shoulder?_____

d) Is there evidence that the water may pond on the shoulder?_____

Are joint sealants or crack sealants in good condition and preventing water from entering the pavement?__

Are the cross drainage conduits closed by debris?_____

AC Pavements

Is there moisture related distress evident such as; Stripping, Rutting, Cracking in Wheelpath, Shoulder Dropoff/Heave, Pumping, Water Bleeding, Swelling?

_____

_____

_____

_____

PCC Pavements

Is there moisture related distress evident such as; Pumping, Faulting, Corner Break, D-Cracking, Edge Joint Opening, Shoulder Dropoff/Heave, Punchout (CRCP only), Swelling, Slab Cracking? _____

_____

_____

_____

_____

Is there evidence of springs and excessively wet areas?_____

Are there slides or slumps noted along the alignment? _____

Specific surface/subsurface drainage recommendations _____

KHN:Q:MT:117.cg

Lab Form No. 111
Revised May 1989

Montana Department of Highways

Preconstruction Soil Survey Data

and Special Recommendations Relative to Subgrade and Road Surface Design

Project Number _____ Designation _____ Length _____ County _____ Date _____

Submitted by _____ Title _____ _____ _____
District Materials Supervisor District Engineer

Sample Number	Date	Location of Boring	Depth	Representing Stationing		Soil Class (MT 214)	LL	PI	10 Mesh	40 Mesh	200 Mesh	Inplace Density	Maximum Dry Density	Percent Natural Moisture	Percent Optimum Moisture	Depth to Water Table	"R" Value (AASHTO T190)

Remarks

MT-207

April 1, 1992

10 of 10

MT 207

MONTANA DEPARTMENT OF TRANSPORTATION

LOG OF BORING

Geotechnical Section

Project Name: EXAMPLE - ENGLISH | Project Number: BR 549(0)

Borehole Location: STA. 13+95, 20.8 ft. Lt. PTW Centerline | Borehole Number: EXAMPLE | Sheet 1 of 1

Drilling Equipment: CME 550 | Hammer Type: Automatic | Driller: A. Driller | Logger: A. Logger

Drilling Fluid: Water | Borehole Diameter (in): 8 | Date Started: 1/1/98 | Date Finished: 1/1/98

Elevation and Datum: Ground: 3739.80 | Casing:

Notes: Legal Description - 01S18E32DAC. Elevation and Station provided by District Survey.

DEPTH (feet)	OPERATION	PRESSURE (psi)	RATE (ipf)	CORE PERCENT RECOVERY	ROCK QUALITY DESIGNATION (RQD)	SAMPLE	RECOVERY (%)	STANDARD PENETRATION TEST SPT	DRY DENSITY (pcf)	MOISTURE CONTENT (%)	LIQUID LIMIT LL	PLASTIC LIMIT PL	GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (feet)	REMARKS
5	DRILL						100	5-10-5		15		NP		Sandy GRAVEL, coarse, subangular, damp, tan, medium dense.	2.0	Hollow stem auger with bullet bits.
10							100		100	30	83	18		CLAY, moist, gray, medium stiff, high plasticity, medium dry strength, slow dilatency, medium toughness.	13.0	qu = 250 psf @ 10 ft.
15							95	3-4-3		27					15.0	
20		500	15	100	65		100	37-50/0.4 ft.						SHALE, moderately fissile, slightly weathered, hard field hardness, black, horizontal bedding.		Switched to NW triple tube core barrel with surface set bit @ 16 ft.
25		700	20	100	88										25.0	

Bottom of Hole Elevation = 3714.80 ft.

EPJ MTDOT.GDT 3/2/98

LOG_OF_BORING

Operation types: Auger; Casing Advancer; Core Barrel; Drive Casing

Sampler Types: Split Spoon; Shelby; Bulk Sample; Grab Sample; Penetrometer; Vane Shear; Special Samplers; Testpit

WATER LEVEL OBSERVATIONS

While Drilling ▽ 12.1 ft | Upon Completion of Drilling ▽ 9.8 ft

Time After Drilling

Depth To Water (feet)

Remarks: Water table at 9.8 ft.

MT 207

MONTANA DEPARTMENT OF TRANSPORTATION

Geotechnical Section

LOG OF BORING

Project Name: SAMPLE - Metric		Project Number:	
Borehole Location:		Borehole Number: -	Sheet 1 of 1
Drilling Equipment:	Hammer Type:	Driller:	Logger:
Drilling Fluid:	Borehole Diameter (mm):	Date Started:	Date Finished:
Elevation and Datum: Ground:	Casing:	Notes:	

DEPTH (m)	OPERATION	PRESSURE (MPa)	RATE (mph)	PERCENT RECOVERY	ROCK QUALITY DESIGNATION (RQD)	SAMPLE	RECOVERY (%)	STANDARD PENETRATION TEST SPT	DRY DENSITY (kN/m³)	MOISTURE CONTENT (%)	LIQUID LIMIT LL	PLASTIC LIMIT PL	GRAPHIC LOG	MATERIAL DESCRIPTION	DEPTH (m)	REMARKS
	DRILL															
0																
2																
4																
6																
8																
10																

Operation Types: Auger; Casing Advancer; Core Barrel; Drive Casing

Sampler Types: Split Spoon; Shelby; Bulk Sample; Grab Sample; Penetrometer; Vane Shear; Special Samplers; Testpit

WATER LEVEL OBSERVATIONS

While Drilling ▽ ____ m Upon Completion of Drilling ▽ ____ m

Time After Drilling

Depth To Water (m)

Remarks:

LOG_OF_BORING_BLANK-M.GPJ_MTDOT.GDT_11/3/99

METHODS OF SAMPLING AND TESTING
MT 208-04
METHOD OF TEST FOR DETERMINING THE LIQUID LIMIT OF SOILS
(Modified AASHTO T 89)
and
METHOD OF TEST FOR DETERMINING
THE PLASTIC LIMIT, AND THE PLASTICITY INDEX OF SOILS
(Modified AASHTO T 90)

1 Definition:

1.1 The Liquid Limit of a soil is that water content, as determined in accordance with the following procedure, at which the soil passes from a plastic to a liquid state.

1.2 The following applies to all specified limits in this standard: For the purposes of determining conformance with theses specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with AASHTO R 11.

2 Referenced Documents:

2.1 ***AASHTO:***
T 89 Determining the Liquid Limit of Soils
T 90 Determining the Plastic Limit and Plastcicty Index of Soils

MT Materials Manual:
MT-200 Dry Preparation of Disturbed Samples for Test
MT-227 Laboratory Determination of Moisture Content of Soils

3 Apparatus:

3.1 *Dish*--A porcelain dish, preferably unglazed, or similar mixing dish, about 115 mm (4½ in.) in diameter.

3.2 *Spatula*--A spatula or pill knife having a blade about 75 mm (3 in.) in length and about 20 mm (¾ in.) in width.

3.3 Liquid Limit Device:

3.3.1 *Manually Operated*--A device consisting of a brass dish and carriage, constructed according to the plan and dimensions shown in Figure 1.

3.3.2 *Mechanically Operated*--A motorized device equipped to produce the rise and rate of shocks to a brass cup as described in sections 4.2 and 5.3 of this procedure, respectively. The cup and the critical dimensions of the device shall conform to those shown in Figure 1 of this procedure. The device shall give the same liquid limit values as obtained with the manually operated device.

3.4 *Grooving Tool*--A grooving tool conforming to the critical dimensions shown in Figure 1. The gage need not be part of the tool.

3.5 *Gage*--A gage, whether attached to the grooving tool or separate, conforming to the critical dimension "d' shown in Figure 1 and may be, if separate, a metal bar 10.0 ± 0.2 mm (0.394 ± 0.008 in.) thick and approximately 50 mm (2 in.) long.

3.6 *Containers*--Suitable containers made of material resistant to corrosion and not subject to change in weight or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial weighing and to prevent absorption of moisture from the atmosphere following drying and before final weighing. One container is needed for each moisture content determination.

3 **Apparatus:** (continued)

3.7 *Balance*--A balance sensitive to 0.01 grams.

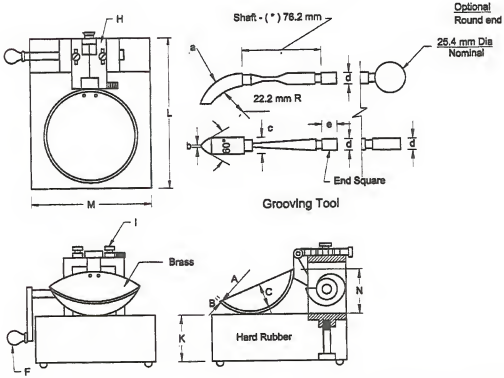
3.8 *Oven*--A thermostatically controlled drying oven capable of maintaining temperatures of 110 ± 5 C (230 ± 9 F) for drying moisture samples.

4 Sample:

4.1 A sample weighing about 100 g shall be taken from the thoroughly mixed portion of the material passing the 0.425 mm (No. 40) sieve which has been obtained in accordance with MT-200, Dry Preparation of Disturbed Soil and Soil Aggregate Sample for Test.

5 Adjustment of Liquid Limit Device:

5.1 The Liquid Limit Device shall be inspected to determine that the device is in good working order; that the pin connecting the cup is not worn sufficiently to permit side play; that the screws connecting the cup to the hanger arm are tight; that the points of contact on the cup and base are not excessively worn; that the lip of the cup is not excessively worn; and that a groove has not been worn in the cup through long usage. The grooving tool shall be inspected to determine that the critical dimensions are as shown in Figure 1 of this method.



	Liquid Limit Device							Grooving Tool				
	Cup Assembly				Base			Curved End			Gage	
Dimension	A	B	C	N	K	L	M	a	b	c	d	*e
Description	Radius of Cup	Thickness of Cup	Depth of Cup	Cup at Cam Follower to Base	Thickness	Length	Width	Thickness	Cutting Edge	Width	Depth	Length
Metric, mm	54	2.0	27	47	50	150	125	10.0	2.0	13.5	10.0	15.9
Tolerance, mm	2	0.1	0	1.5	5	5	5	0.1	0.1	0.1	0.2	—

Note: Plate "H" may be designed for using (1) one securing screw (I).
An additional wear tolerance of 0.1 mm shall be allowed for dimension "b" for used grooving tools.
Feet for base shall be of resilient material.
(*) Nominal dimensions.
All tolerances specified are plus or minus (±) except as noted above.

Figure 1—Manual Liquid Limit Device

Note 3 - Wear is considered excessive when the point of contact on the cup or base exceeds approximately 13 mm (0.5 in.) in diameter, or when any point on the rim of the cup is worn to approximately ½ the original thickness. Although a slight groove in the center of the cup is noticeable, it is not objectionable. If the groove becomes pronounced before other signs of wear appear, the cup should be considered excessively worn. Excessively worn cups shall be replaced. A base which is excessively worn may be refinished as long as the thickness does not exceed the tolerance shown in Figure 1 by more than -2.5 mm (-0.1 in.) and the distance between the cup at the cam follower and the base is maintained within the tolerances specified in Figure 1.

5.2 Adjust the height of drop of the cup so that the point on the cup that comes in contact with the base rises to a height of 10 ± 0.2 mm (0.394 ± 0.008 in.). See Figure 2 for proper location of the gage relative to the cup during adjustment.

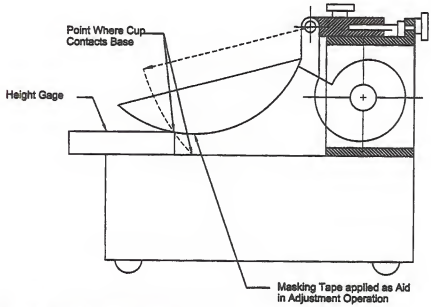


Figure 2—Calibration for Height of Drop

Note 4 - A convenient procedure for adjusting the height of drop is as follows: place a piece of masking tape across the outside bottom of the cup parallel with the axis of the cup hanger pivot. The edge of the tape away from the cup hanger should bisect the spot on the cup that contacts the base. For new cups, placing a piece of carbon paper on the base and allowing the cup to drop several times will mark the contact spot. Attach the cup to the device and turn the crank until the cup is raised to its maximum height. Slide the height gage under the cup from the front, and observe whether the gage contacts the cup or the tape. See Figure 2. If the tape and cup are both contacted, the height of drop is approximately correct. If not, adjust the cup until simultaneous contact is made. Check adjustment by turning the crank at two revolutions per second while holding the gage in position against the tape and cup. If a ringing or clicking sound is heard without the cup rising from the gage, the adjustment is correct. If no ringing is heard or if the cup rises from the gage, readjust the height of drop. If the cup rocks on the gage during this checking operation, the cam follower pivot is excessively worn and the worn parts should be replaced. Always remove tape after completion of adjustment operation.

6 Procedure:

6.1 The soil sample shall be placed in the mixing dish and thoroughly mixed with 15 to 20 ml of distilled or demineralized water by alternately and repeatedly stirring, kneading and chopping with a spatula. Further additions of water shall be made in increments of 1 to 3 ml. Each increment of water shall be thoroughly mixed with the soil as previously described before another increment of water is added. Once testing has begun, no additional dry soil should be added to the moistened soil. The cup of the Liquid Limit Device shall not be used for mixing soil and water. If too much moisture has been added to the sample, the sample shall either be discarded, or mixed and kneaded until natural evaporation lowers the closure point into an acceptable range.

Note 5 - Some soils are slow to absorb water, therefore, it is possible to add the increments of water so fast that a false liquid limit value is obtained. This can be avoided if more mixing and/or time is allowed. Tap water may be used for routine testing if comparative tests indicate no differences in results between using tap water and distilled or demineralized water. However, referee or disputed tests shall be performed using distilled or demineralized water.

6.2 When sufficient water has been thoroughly mixed with the soil to form a uniform mass of stiff consistency, a sufficient quantity of this mixture shall be placed in the cup above the spot where the cup rests on the base and shall be squeezed and spread with the spatula to level and at the same time trimmed to a depth of 10 mm at the point of maximum thickness. As few strokes of the spatula as possible shall be used, care being taken to prevent the entrapment of air bubbles within the mass. With the spatula the soil shall be leveled and at the same time trimmed to a depth of 10 mm at the point of maximum thickness. The excess soil shall be returned to the mixing dish. The soil in the cup of the device shall be divided by a firm stroke of the grooving tool along the diameter through the centerline of the cam follower so that a clean sharp groove of the proper dimensions will be formed as shown in Figure 3. To avoid tearing of the sides of the groove or slipping of the soil cake on the cup, up to six strokes from front to back or from back to front counting as one stroke, shall be permitted. The depth of the groove should be increased with each stroke and only the last stroke should scrape the bottom of the cup.

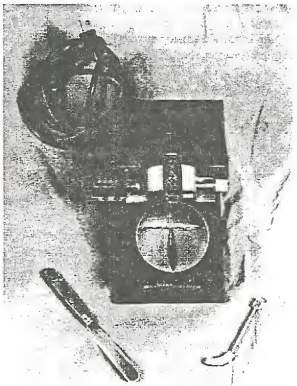


Figure 3—Liquid Limit Device With Soil Sample in Place

6 Procedure: (continued)

6.3 The cup containing the sample prepared as described in 6.2 shall be lifted and dropped by turning the crank F at the rate of approximately two revolutions per second until the two sides of the sample come in contact at the bottom of the groove along a distance of about 13 mm (0.5 in.). The number of shocks required to close the groove this distance shall be recorded. The base of the machine shall not be held with the free hand while the crank F is turned.

Note 6 - Some soils tend to slide on the surface of the cup instead of flowing. If this occurs, more water should be added to the sample and remixed, then the soil-water mixture placed in the cup, a groove cut with the grooving tool and 6.2 repeated. If the soil continues to slide on the cup at a lesser number of blows than 25, the test is not applicable and a note should be made that the liquid limit could not be determined.

6.4 A slice of soil approximately the width of the spatula, extending from edge to edge of the soil cake at right angles to the groove and including that portion of the groove in which the soil flowed together, shall be removed and placed in a suitable container. The container and soil shall then be weighed promptly and the weight recorded. The soil in the container shall be oven-dried to a constant weight at 110 ± 5 C (230 ± 9 F) and weighed. This weight shall be recorded and the loss in weight due to drying shall be recorded as the weight of water.

6.5 The soil remaining in the cup shall be transferred to the mixing dish. The cup and grooving tool shall then be washed and dried in preparation for the next trial.

6.6 The foregoing operations shall be repeated for at least two additional portions of the sample to which sufficient water has been added to bring the soil to a more fluid condition. The object of this procedure is to obtain samples of such consistency that at least one determination will be made in each of the following ranges of shocks: 25-35, 20-30, 15-25, so the range in the three determinations is at least 10 shocks.

7 Calculation:

7.1 The water content of the soil shall be expressed as the moisture content in the percentage of the weight of the oven-dried soil and shall be calculated as follows:

$$\text{Percentage moisture} = \frac{\text{mass of water}}{\text{mass of oven dried soil}} \times 100$$

7.1.1 Calculate the percentage of moisture to the nearest whole percent.

8 Preparation of Flow Curve:

8.1 A "Flow Curve" representing the relation between moisture content and corresponding number of shocks shall be plotted in a semi-logarithmic graph with the moisture contents as abscissae on the arithmetical scale, and the number of shocks as ordinates on the logarithmic scale. The flow curve shall be a straight line drawn as nearly as possible through the three or more plotted points.

9 Liquid Limit:

9.1 The moisture content corresponding to the intersection of the flow curve with the 25 shock ordinate shall be taken as the liquid limit of the soil. Report this value to the nearest whole number.

METHOD B

10 Sample:

10.1 A sample weighing about 50 g shall be taken as described in 4.1.

11 Procedure:

11.1 The procedure shall be the same as prescribed in Sections 6.1 through 6.5 except that the initial amount of water to be added in accordance with Section 6.1 shall be approximately 8 to 10 ml and the moisture sample taken in accordance with Section 6.4 shall be taken only for the accepted trial.

11.2 For accuracy equal to that obtained by the standard three-point method, the accepted number of blows for groove closure shall be restricted between 22 and 28 blows. After obtaining a preliminary closure in the acceptable blow range, immediately return the soil remaining in the cup to the mixing dish and, without adding any additional water, repeat as directed in Sections 6.2 and 6.3. If the second closure occurs in the acceptable range (22 – 28 inclusive) and the second closure is within two (2) blows of the first closure, secure a water content specimen as directed in Section 6.4.

11.3 Groove closures between 15 and 40 blows may be accepted if variations of ± 5 percent of the true liquid limit are tolerable.

12 Calculation:

12.1 The water content of the soil at the time of the accepted closure shall be calculated in accordance with Section 7.1.

13 Liquid Limit:

13.1 The liquid limit shall be determined by one of the following methods: the nomograph, Figure 4; the multicurve; Figure 5; the slide rule with a special "blows" scale, Figure 6, or by any other method of calculation that produces equally accurate liquid limit values. The standard three-point method shall be used as a referee test to settle all controversies.

13.2 The key in Figure 4 illustrates the use of the nomograph (mean slope).

13.3 The chart (multi-flow curve), Figure 5, is used by plotting on it a point representing the moisture content vs. number of blows for the accepted trial, and drawing a line through the plotted point parallel to the nearest chart curve. The moisture content corresponding to the intersection of this line with the 25-blow line shall be recorded as the liquid limit.

13.4 The special slide rule, Figure 6, is used by setting the hairline of the indicator slide coincident with the A-scale value of the moisture content for the accepted groove closure, and moving the special scale until the number of blows used for closure is also under the hairline. The liquid limit will then be found on the A-scale opposite the end index of the B-scale, or opposite the middle index of the B-scale, which in turn is directly in line with the 25-blow mark of the special scale.

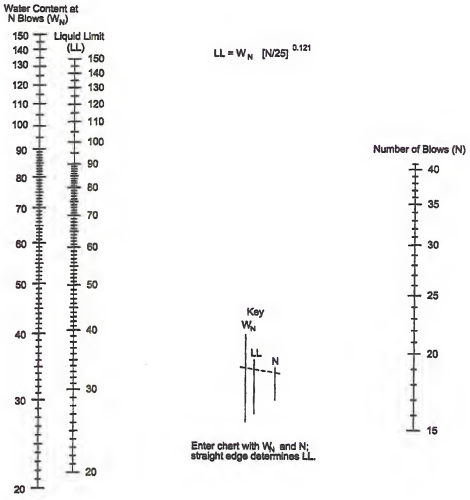


Figure 4—Nomographic chart Developed by the Waterways Experiment Station, Corps of Engineers, U.S. Army, to Determine Liquid Limit Using Mean Slope Method

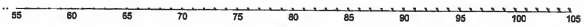


Figure 5—Chart Developed by Washington State Highway Department for the Calculation of the Liquid Limit

FIGURE 5 Chart Developed by Washington State Highway Department for the Calculation of

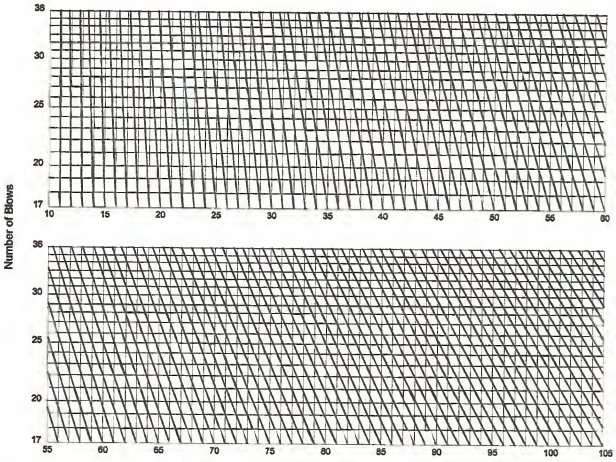
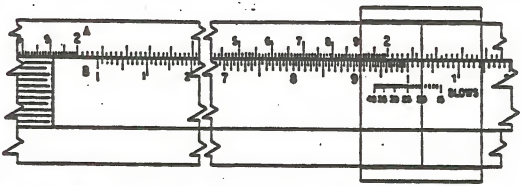


Figure 5—Chart Developed by Washington State Highway Department for the Calculation of the Liquid Limit

A - LOCATION OF SPECIAL SCALE (BLOWS) WITH RESPECT TO B SCALE OF SLIDE RULE



B - SLIDE RULE SET FOR 21.4 PERCENT MOISTURE AT 20 BLOWS, INDICATING CALCULATED LIQUID LIMIT OF 20.8

14 Method to be Used:

14.1 In making check or referee tests, Method A shall be used. The results of liquid limit tests are influenced by:

14.1.1 The time required to make the test.

14.1.2 The moisture content at which the test is begun.

14.1.3 The addition of dry soil to the seasoned sample.

15 Procedure:

15.1 Therefore, in making the liquid limit test for check, or referee purposes, the following time schedule shall be used:

15.1.1 Mixing of soil with water -- 5 to 10 minutes, the longer period being used for the more plastic soils.

15.1.2 Seasoning under a damp cloth -- 30 minutes.

15.1.3 Remixing before placing in the brass cup -- add 1 ml of water and mix for 1 minute.

15.1.4 Placing in the brass cup and testing -- 3 minutes.

15.1.5 Adding water and remixing -- 3 minutes.

15.2 No trial requiring more than 35 blows or less than 15 blows shall be recorded. In no case shall dried soil be added to the seasoned soil being tested.

METHODS OF SAMPLING AND TESTING
MT-208
METHOD OF TEST FOR DETERMINING
THE PLASTIC LIMIT, AND THE PLASTICITY INDEX OF SOILS
(Modified AASHTO T 90)

1 Scope:

1.1 The plastic limit of a soil is the lowest water content determined in accordance with the following procedure at which the soil remains plastic. The plasticity index of a soil is the range in water content, expressed as a percentage of the mass of the oven-dried soil, within which the material is in a plastic state. It is the numerical difference between the liquid limit and plastic limit of the soil.

1.2 The following applies to all specified limits in this standard: For the purposes of determining conformance with theses specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with AASHTO R 11.

2 Referenced Documents:

MT Materials Manual
MT-200 Dry Preparation of Disturbed Samples for Test
MT-208 Determining the Liquid Limit of Soils
MT 227 Laboratory Determination of Moisture Content of Soils

3 Apparatus:

3.1 *Dish* – A porcelain evaporating dish, or similar mixing dish about 115 mm in diameter.

3.2 *Spatula* – A spatula or pill knife having a blade about 75 mm in length and about 20 mm in width.

3.3 *Surface for Rolling* – A ground glass plate or piece of smooth, unglazed paper on which to roll the sample.

3.4 *Containers* - Suitable containers made of material resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. Containers shall have close fitting-lids to prevent loss of moisture from samples before initial weighing and to prevent absorption of moisture from the atmosphere following drying and before final weighing. One container is needed for each moisture content determination.

3.5 *Balance* – The balance shall sufficient capacity and conform to AASHTO M 231, Class G1.

3.6 *Oven* – A thermostatically controlled drying oven capable of maintaining temperatures of 110 ± 5°C (230 ± 9°F) for drying samples.

4 Sample:

4.1 If the plastic limit only is required, take a quantity of soil weighing about 20 g from the thoroughly mixed portion of the material passing the 0.425 mm (No. 40) sieve, obtained in accordance with paragraph 3.1. Place the air-dried soil in a mixing dish and thoroughly mix with distilled or demineralized water until the mass becomes plastic enough to be easily shaped into a ball. Take a portion of this ball weighing about 8 g for the test sample.

Note 1 - Tap water may be used for routine testing if comparative tests indicate no differences in results between using tap water and distilled or demineralized water. However, referee or disputed tests shall be performed using distilled or demineralized water.

4.2 If both the liquid and plastic limits are required, take a test sample weighing about 8 g from the thoroughly wet and mixed portion of the soil prepared in accordance with the Standard Method of

Test for Liquid Limit for Soils (MT-208). Take the sample at any stage of the mixing process at which the mass becomes plastic enough to be easily shaped into a ball without sticking to the

4 **Sample:** (continued)

fingers excessively when squeezed. If the sample is taken before completion of the liquid limit test, set it aside and allow to season in air until the liquid limit test has been completed. If the sample taken during the liquid limit test is to dry to permit rolling to a 3 mm (1/8 in.) thread, add more water and remix.

5 **Procedure:**

5.1 Select a 1.5 to 2.0 g portion from the mass taken in accordance with Section 4. Form the selected portion into an ellipsoidal mass.

5.2 Use one of the following methods to roll the soil mass into a 3 mm diameter thread at a rate of 80 to 90 strokes per minute, counting a stroke as one complete motion of the hand forward and back to the starting position again.

5.2.1 *Hand Rolling Method* - Roll the mass between the fingers and the ground-glass plate (or a piece of paper laying on a smooth horizontal surface) with just sufficient pressure to roll the mass into a thread of uniform diameter throughout its length. The thread shall be further deformed on each stroke so that its diameter reaches 3 mm, taking no more than 2 min. The amount of hand or finger pressure required will vary greatly, according to the soil. Fragile soils of low plasticity are best rolled under the outer edge of the palm or at the base of the thumb.

5.2 When the diameter of the thread becomes 3 mm (1/8 in.), break the thread into six or eight pieces. Squeeze the pieces together between the thumbs and fingers of both hands into a uniform mass roughly ellipsoidal in shape and reroll. Continue this alternate rolling to a thread 3 mm (1/8 in.) in diameter, gathering together, kneading and rerolling, until the thread crumbles under the pressure required for rolling and the soil can no longer be rolled into a thread. The crumbling may occur when the thread has a diameter greater than 3 mm (1/8 in.). This shall be considered a satisfactory end point, provided the soil has been previously rolled into a thread 3 mm (1/8 in.) in diameter. The crumbling will manifest itself differently with the various types of soil. Some soils fall apart in numerous small aggregations of particles; others may form an outside tubular layer that starts splitting at both ends. The splitting progresses toward the middle, and finally, the thread falls apart in many small platy particles. Heavy clay soils require much pressure to deform the thread, particularly as they approach the plastic limit, and finally, the thread breaks into a series of barrel-shaped segments each about 6.4 to 9.5 mm (¼ to _ in.) in length. At no time shall the operator attempt to produce failure at exactly 3 mm (1/8 in.) diameter by allowing the thread to reach 3 mm (1/8 in.) diameter by allowing the thread to reach 3 mm (1/8 in.) then reducing the rate of rolling or the hand pressure, or both, and continuing rolling without further deformation until the thread falls apart. It is permissible, however, to reduce the total amount of deformation for feebly plastic soils by making the initial diameter of the ellipsoidal-shaped mass bearer to the required 3 mm (1/8 in.) final diameter.

5.3 Gather the portions of the crumbled soil together and place in a weighed container. Immediately cover the container.

5.4 Repeat the operations described in sections 5.1 through 5.3 until the 8 g specimen is completely tested. Determine the moisture content of the soil in the containers in accordance with MT-227, and record the results.

6 Calculations:

6.1 Calculate the plastic limit, expressed as the water content in percentage of the mass of the oven-dry soil, as follows:

$$\text{Percentage moisture} = \frac{\text{mass of water}}{\text{mass of oven dried soil}} \times 100$$

Report the plastic limit to the nearest whole number.

6.2 Calculate the plasticity index of a soil as the difference between its liquid limit and its plastic limit, as follows:

Plastic index = liquid limit - plastic limit

6.3 Report the difference calculated as indicated in 6.2 as the plasticity index, except under the following conditions:

6.3.1 When the liquid limit or plastic limit cannot be determined, report the plasticity index as NP (non plastic).

6.3.2 When the plastic limit is equal to, or greater than, the liquid limit, report the plasticity index as NP.

METHODS OF SAMPLING AND TESTING
MT 209-04
METHOD OF TEST FOR
RESISTANCE TO ABRASION OF SMALL SIZE COARSE AGGREGATE
BY USE OF THE LOS ANGELES MACHINE
(Modified AASHTO T 96)

1 Scope:

1.1 This method covers a procedure for testing sizes of coarse aggregate smaller than 37.5 mm (1½ in.) for resistance to abrasion using the Los Angeles testing machine.

Note 1 - A procedure for testing coarse aggregate larger than 19.0 mm (¾ in.) is covered in the Method of Test for Resistance to Abrasion of Large Size Coarse Aggregate by the Los Angeles Machine (ASTM C 535).

2 Referenced Documents:

2.1 ***AASHTO:***
T 2 Sampling Aggregates
T 96 Resistance to Degrdation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine

MT Manual:
MT-202 Sieve Analysis of Fine and Coarse Aggregates
MT-405 Wire Cloth Sieves for Testing Purposes
MT-417 Reducing Field Samples of Aggregate to Testing Size

ASTM:
C 535 Test for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
C 670 Practice for Preparing Precision Statement for Test Methods for Construction Materials

3 Description of Terms:

3.1 *Constant Mass*-Test samples dried at a temperature of 110 ± 5°C (230 ± 9°F) to a condition such that it will not lose more than 0.1 percent moisture after 2 h of drying. Such a condition of dryness can be verified by weighing the sample before and after successive 2 h drying periods. In lieu of such a determination, samples may be considered to have reached constant mass when they have been dried at a temperature of 110 ± 5°C (230 ± 9°F) for an equal or longer period than that previously found adequate for producing the desired constant mass condition under equal or heavier loading conditions of the oven.

4 Apparatus:

4.1 *Los Angeles Machine*-The Los Angeles abrasion testing machine equipped with a counter and conforming in all its essential characteristics to the design shown in AASHTO T 96 shall be used. The machine shall consist of a hollow steel cylinder, closed at both ends, having an inside diameter of 711± 5 mm (28 ± 0.2 in.) and an inside length of 508 ± 5 mm (20 ± 0.2 in.). The cylinder shall be mounted on stub shafts attached to the ends of the cylinder but not entering it, and shall be mounted in such a manner that it may be rotated with the axis in a horizontal position within a tolerance in slope of 1 in 100. An opening in the cylinder shall be provided for the introduction of the test sample. A suitable, dust-tight cover shall be provided for the opening with means for bolting the cover in place. The cover shall be so designed as to maintain the cylindrical contour of the interior surface unless the shelf is to located that the charge will not fall on the cover, or come in contact with it during the test. A removable steel shelf extending the full length of the cylinder and projecting inward 89 ± 2 mm (3.5 ± 0.1 in.) shall be mounted on the interior cylindrical surface of the cylinder, or on the inside surface of the cover, in such a way that a plane centered between the large faces coincides with an axial plane. The shelf shall be of such thickness and so mounted, by bolts or other suitable means, as to be firm and rigid. The position

4 Apparatus: (continued)

of the shelf shall be such that the distance from the shelf to the opening, measured along the outside circumference of the cylinder in the direction of the rotation, shall not be less than 1.27 m (50 in.).

Note 2 - The use of a wear-resistant steel, rectangular in cross-section and mounted independently of the cover, is preferred. However, a shelf consisting of a section of rolled angle, properly mounted on the inside of the cover plate, may be used provided the direction of rotation is such that the charge will be caught on the outside face of the angle. If the shelf becomes distorted from its original shape to such an extent that the requirements given in A1.2 of the Appendix to this method are not met, the shelf shall either be repaired or replaced before additional abrasion tests are made.

4.1.1 The machine shall be so driven and so counterbalanced as to maintain a substantially uniform peripheral speed. (Note 3). If an angle is used as the shelf, the direction of rotation shall be such that the charge is caught on the outside surface of the angle.

Note 3 - Back-lash or slip in the driving mechanism is very likely to furnish test results which are not duplicated by other Los Angeles machines producing constant peripheral speed.

4.2 *Sieves,* conforming to the Specifications for Wire-Cloth Sieves for Testing Purposes (MT-405).

4.3 *Balance*-The balance shall have a capacity over 2,000 grams thru 5,000 grams, sensitive to 1.0 grams, and with an accuracy of 1.0 gram or 0.1%.

4.4 *Oven*-The oven shall be capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F).

4.5 *Charge*-The charge shall consist of steel spheres averaging approximately 1 27/32 in. (46.8 mm) in diameter and each weighing between 390 and 445 g. (Note 4)

4.5.1 The charge, depending upon the grading of the test sample as described in Section 8, shall be as follows:

Grading	Number of Spheres	Weight of Charge, g
A	12	5,000± 25
B	11	4,584± 25
C	8	3,330± 20
D	6	2,500± 15

Note 4 - Steel ball bearings 1 13/16 in. (46.0 mm) and 1 7/8 in. (47.6 mm) in diameter, weighing approximately 400 and 440 g each, respectively, are readily available. Steel spheres 1 27/32 in. (46.8 mm) in diameter weighing approximately 420 g may also be obtainable. The charge may consist of a mixture of these sizes conforming to the weight tolerances of Sections 4.5 and 4.5.1.

5 Sampling:

5.1 The field sample shall be obtained in accordance with T 2 and reduced to test portion size in accordance with T 248.

6 Test Sample:

6.1 The test sample shall be washed and oven-dried to a constant mass as described in Section 3 (Note 5), separated into individual size fractions, and recombined to the grading of Table 1 most nearly corresponding to the range of sizes in the aggregate furnished for the work. The weight of the sample prior to test shall be recorded to the nearest 1.0 g.

7 Procedure:

7.1 Place the test sample and the charge in the Los Angeles testing machine and rotate the machine at a speed of 30 to 33 rpm for 500 revolutions. After the prescribed number of revolutions, discharge the material from the machine and make a preliminary separation of the sample on a sieve coarser than the 1.70 mm (No. 12). Sieve the finer portion on a 1.70 mm sieve in a manner conforming to MT-202. Wash the material coarser than the 1.70 mm sieve (Note 5), oven-dry to a constant mass, and weigh to the nearest 1.0 g (Note 6).

Note 5 - If the aggregate is essentially free of adherent coatings and dust, the requirement for washing before and after test may be waived. Elimination of washing after test will seldom reduce the measured loss by more than about 0.2% of the original sample weight.

Note 6 - Valuable information concerning the uniformity of the sample under test may be obtained by determining the loss after 100 revolutions. This loss should be determined without washing the material coarser than the 1.70-mm sieve. the ratio of the loss after 100 revolutions to the loss after 500 revolutions should not greatly exceed 0.20 for material of uniform hardness. When this determination is made, take care to avoid losing any part of the sample; return the entire sample, including the dust of fracture, to the testing machine for the final 400 revolutions required to complete the test.

8 Calculation:

8.1 Express the loss (difference between the original weight and the final weight of the test sample) as a percentage of the original weight of the test sample. Report this value as the percent loss.

Table 1 - Gradings of Test Samples

Sieve Size		Mass of Indicated Sizes, % Grading			
Passing	Retained on	A	B	C	D
mm					
37.5 (1 1/2 in.)	25.0 (1 in.)	1,250± 25	---	---	---
25.0 (1 in.)	19.0 (3/4 in.)	1,250± 25	---	---	---
19.0 (3/4 in.)	12.5 (1/2 in.)	1,250± 10	2,500± 10	---	---
12.5 (1/2 in.)	9.5 (3/4 in.)	1,250± 10	2,500± 10	---	---
9.5 (3/4 in.)	6.3 (1/4 in.)	---	---	2,500± 10	---
6.3 (1/4 in.)	4.75 (No. 4)	---	---	2,500± 10	---
4.75 (No. 4)	2.36 (No. 8)	---	---	---	5,000± 10
Total		5,000± 10	5,000± 10	5,000± 10	5,000± 10

Note 7 - The percent loss determined by this method has no known consistent relationship to the percent loss for the same material when tested by ASTM C 535.

APPENDIX

A1 Maintenance of Shelf

A1.1 The shelf of the Los Angeles Machine is subject to severe surface wear and impact. With use, the working surface of the shelf is peened by the balls and tends to develop a ridge of metal parallel to and about 32 mm (1¼ in.) from the junction of the shelf and the inner surface of the cylinder. If the shelf is made from a section of rolled angle, not only may this ridge develop but the shelf itself may be bent longitudinal or transversely from its proper position.

A1.2 The shelf should be inspected periodically to determine that it is not bent either lengthwise or from its normal radial position with respect to the cylinder. If either condition is found, the shelf should be repaired or replaced before further abrasion tests are made. The influence on the test result of the ridge developed by peening of the working face of the shelf is not known. However, for uniform test conditions, it is recommended that the ridge be ground off if its height exceeds 2 mm (0.1 in.).

METHODS OF SAMPLING AND TESTING
MT 210-04
METHOD OF TEST FOR THE MOISTURE-DENSITY RELATIONS OF SOILS USING A 5 LB. (2.5 KG) RAMMER AND A 12 IN. (305 MM) DROP
(Modified AASHTO T 99)

1 Scope:

1.1 These methods of test are intended for determining the relation between the moisture content and density of soils compacted in a mold of a given size with a 5.5 lb. (2.5 kg) rammer dropped from a height of 12 in. (305 mm). Four alternate procedures are provided as follows:
Method A--A 4 in. (101.60 mm) mold: soil material passing a 4.75 mm (No. 4) sieve Sections 3 and 4.
Method B--A 6 in. (152.40 mm) mold: soil material passing a 4.75 mm (No. 4) sieve Sections 5 and 6.
Method C--A 4 in. (101.60 mm) mold: soil material passing a 19.0 mm (¾ in.) sieve Sections 7 and 8.
Method D--A 6 in. (152.40 mm) mold: soil material passing a 19.0 mm (¾ in.) sieve Sections 9 and 10.

1.2 The method to be used should be indicated in the specifications for the material being tested. If no method is specified, the provisions of Method A shall govern.

2 Referenced Documents;

2.1 ***AASHTO:***
T 99 Moisture-Density Relations of Soils Using a 5.5 lb. Rammer with a 12 Inch Drop
M 92 Wire Cloth and Sieves for Testing Purposes

MT Manual:
MT-203 Unit Weight of Aggregate
MT-405 Wire Cloth Sieves for Testing Purposes

3 Apparatus:

3.1 *Molds*--The molds shall be solid-wall, metal cylinders manufactured with dimensions and capacities shown in 2.1.1 and 2.1.2 below. They shall have a detachable collar assembly approximately 2.375 in. (60 mm) in height, to permit preparation of compacted specimens of soil-water mixtures of the desired height and volume. The mold and collar assembly shall be so constructed that it can be fastened firmly to a detachable base plate made of the same material (Note 1).

Note 1 - Alternate types of molds with capacities as stipulated herein may be used, provided the test results are correlated with those of the solid-wall mold on several soil types and the same moisture-density results are obtained. Records of such correlation shall be maintained and readily available for inspection, when alternate types of molds are used.

3.1.1 A 4 in.(101.60 mm) Mold having a capacity of 1/30 (0.0333) ± 0.0003 cu. ft. (0.000943 ± 0.000008 m^3) with an internal diameter of 4.000 ± 0.016 in. (101.6 ± 0.41 mm) and a height of 4.584 ± 0.005 in. (116.43 ± 0.13 mm).

3.1.2 A 6 in. (152.40 mm) Mold having a capacity of 1/13.33 (0.07500 ± 0.00075 cu. ft. (0.002124 ± 0.000021 m^3) with an internal diameter of 6.000 ± 0.026 in. (152.4 ± 0.66 mm) and a height of 4.584 ± 0.005 in. (116.43 ± 0.13 mm).

3 Apparatus: (continued)

3.1.3 *Molds Out of Tolerance Due to Use*--A mold that fails to meet manufacturing tolerances after continued service may remain in use provided those tolerances are not exceeded by more than 50 percent; and the volume of the mold, calibrated in accordance with Sec. 6 (Calibration of Measure) of MT-203, for Unit Weight of Aggregate, is used in the calculations.

3.2 *Rammer:*

3.2.1 *Manually Operated*--Metal rammer having a flat circular face of 2.000 ± 0.01 in. (50.80 ± 0.12 mm) diameter, a wear tolerance of 0.01 in. (0.25 mm) and weighing 5.50 ± 0.02 lb, (2.495 ± 0.009 kg). The rammer shall be equipped with a suitable guide-sleeve to control the height of drop to a free fall of 12.00 ± 0.06 (or 1/16) in. (305 ± 2 mm) above the elevation of the soil. The guide-sleeve shall have at least 4 vent holes, no smaller than 3/8 in. (9.5 mm) diameter spaced approximately 90 deg. (1.57 rad) apart and approximately ¾ in. (19 mm) from each end; and shall provide sufficient clearance so the free fall of the rammer shaft and head is unrestricted.

3.2.2 *Mechanically Operated*--A metal rammer which is equipped with a device to control the height of drop to a free fall of 12.00 ± 0.06 (or 1/16) in. (305 ± 2 mm) above the elevation of the soil and uniformly distributes such drops to the soil surface (Note 2). The rammer shall have a flat circular face 2.000 ± 0.01 in. (50.80 ± 0.127 mm) diameter, a wear tolerance of 0.01 in. (0.25 mm) and a manufactured mass of 5.50 ± 0.02 lb. (2.495 ± 0.009 kg). The mechanical rammer shall be calibrated by ASTM Method D 2168 to give the same moisture-density results as with a manually operated rammer.

Note 2 - It may be impractical to adjust the mechanical apparatus so the free fall is 12 in. (305 mm) each time the rammer is dropped, as with the manually operated rammer. To make the adjustment of free fall, the portion of loose soil to receive the initial blow should be slightly compressed with the rammer to establish the point of impact from which the 12 in. (305 mm) drop is determined. Subsequent blows on the layer of soil being compacted may all be applied by dropping the rammer from a height of 12 in.

3.2.3 *Rammer Face*--The circular face rammer shall be used but a sector face may be used as an alternative provided the report shall indicate type of face used other than the 2 in. (50.8 mm) circular face and it shall have an area equal to that of the circular face rammer.

3.3 *Sample Extruder*--A jack, lever, frame, or other device adopted for the purpose of extruding compacted specimens from the mold.

3.4 *Balances and Scales*--A balance or scale of at least 25 lb. capacity having a sensitivity and readability to 0.01 lb., or a balance or scale having a capacity of approximately 11.5 kg and a sensitivity and readability to 5 grams. (Note 3) Also, a balance of at least 1 kg capacity with a sensitivity and readability to 0.1 g.

Note 3 - The capacity of the metric balance or scale should be approximately 11.5 kg when used to weigh the 6 in. (152 mm)mold and compacted, moist soil; however, when the 4-in. (102 mm) mold is used, a balance or scale of lesser capacity than the 11.5 kg may be used, if the sensitivity and readability is 5 g.

3.5 *Drying Oven*--A thermostatically controlled drying oven capable of maintaining a temperature of 110 ± 5° C (230 ± 9° F) for drying moisture samples.

3.6 *Straightedge*--A hardened-steel straightedge at least 10 in. (250 mm) in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.01 in. per 10 in. (0.1 percent) (0.250 mm per 250 mm) of length within the portion used for trimming the soil (Note 4).

3 Apparatus: (continued)

Note 4 - The beveled edge may be used for final trimming if the edge is true within a tolerance of 0.001 in. per 10 in. (0.1 percent) (0.250 mm per 250 mm) of length; however, with continued use, the cutting edge may become excessively worn and not suitable for trimming the soil to the level of the mold. The straightedge should not be so flexible that trimming the soil with the cutting edge will cause a concave soil surface.

3.7 ***Sieves***—2-in. (50 mm), ¾-in. (19.0 mm), and No. 4 (4.75 mm) sieves conforming to the requirements of MT-405 (AASHTO M 92), Sieves for Testing Purposes.

3.8 *Mixing Tools*--Miscellaneous tools such as mixing pan, spoon trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

3.9 *Containers*--Suitable containers made of material resistant to corrosion and not subject to change in weight or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial weighing and to prevent absorption of moisture from the atmosphere following drying and before final weighing. One container is needed for each moisture content determination.

METHOD A

4 Sample:

4.1 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of drying apparatus such that the temperature of the sample does not exceed 60° C (140° F). Then thoroughly break up the aggregations in such a manner to avoid reducing the natural size of individual particles.

4.2 Sieve an adequate quantity of the representative pulverized soil over the No. 4 (4.75 mm) sieve. Discard the coarse material, if any, retained on the No. 4 (4.75 mm) sieve.

4.3 Select a representative sample, with a mass of approximately 7 lb. (3 kg) or more, of the soil prepared as described in Sections 4.1 and 4.2.

5 Procedure:

5.1 Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately four percentage points below optimum moisture content.

5.2 Form a specimen by compacting the prepared soil in the 4 in. (101.60 mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5 in. (125 mm). Prior to compaction, place the loose soil into the mold and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose or fluffy state, using either the manual compaction rammer or a similar device having a face diameter of approximately 2 inches (50 mm). Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 12 in. (305 mm) above the elevation of the soil when a sleeve-type rammer is used, or from 12 in. (305 mm) above the approximate elevation of compacted soil when a stationary mounted type of rammer is used. During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation (Note 5).

Note 5 - Each of the following has been found to be a satisfactory base on which to rest the mold during compaction of the soil: A block of concrete, weighing not less than 200 lb. (90 kg), supported by a relatively stable foundation; a sound concrete floor; and for field application, such surfaces as found in concrete box culverts, bridges, and pavements.

5.2.1 Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge, and weigh the mold and moist soil in pounds, to the

5 Procedure: (continued)

nearest 0.01 lb., or weigh in kilograms to the nearest 5 grams. For molds conforming to tolerances given in Section 3.1.1 and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 30, and record the result as the wet density, W_1, in pounds per cubic foot, of compacted soil. For molds conforming to tolerances given in Section 3.1.1 and masses recorded in kilograms, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 1059.43, and record the result as the wet density, W_1, in kilograms per cubic meter, of compacted soil. For used molds out of tolerance by not more than 50 percent (3.1.3), use the factor for the molds as determined in accordance with Section 6 (Calibration of Measure), MT-203.

5.3 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material from one of the cut faces, weigh immediately, and dry in an oven at 110 ± 5°C (230 ± 9°F) for at least 12 hours, or to a constant mass to determine the moisture content. The moisture sample shall weigh not less than 100 g.

5.4 Thoroughly break up the remaining portion of the molded specimen until it will pass a No. 4 (4.75 mm) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amount to increase the moisture content of the soil by one or two percentage points, and repeat the above procedure for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet unit mass. W_1, per cubic foot or cubic meter of the compacted soil (Note 6).

Note 6 - This procedure has been found satisfactory in most cases. However, in instances where the soil material is fragile in character and will reduce significantly in grain size due to repeated compaction, and in cases where the soil is a heavy-textured clayey material into which it is difficult to incorporate water, a separate and new sample shall be used in each compaction test. In these cases, separate samples shall be thoroughly mixed with amounts of water sufficient to cause the moisture contents of the samples to vary by approximately two percentage points. The moisture points selected shall bracket the optimum moisture content, thus providing samples which when compacted will increase in mass to the maximum density and then decrease in mass. The samples of soil-water mixtures shall be placed in covered containers and allowed to stand for not less than 12 hours before making the moisture-density test.

5.4.1 In instances where the soil material is fragile in character and will be reduced significantly in grain size by repeated compaction, a separate and new sample shall be used in each compaction test.

METHOD B

6 Sample:

6.1 Select the representative sample in accordance with 4.3, except that it shall have a mass of approximately 16 lb. (7 kg).

7 Procedure:

7.1 Follow the same procedure as described for Method A in Section 4, except for the following: Form a specimen by compacting the prepared soil in the 6-in. (152.4 mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5 in. (125 mm), each layer being compacted by 56 uniformly distributed blows from the rammer. For molds conforming to tolerances in 3.1.2, and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 13.3, and record the result as the wet density, W_1, in lb. ft.^{3}, of the compacted soil. For molds conforming to tolerances given in 3.1.2 and masses recorded in kilograms, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 471, and record the results as the wet density, W_1, in kg/m^3, of compacted soil. For used molds out of tolerance by not more than 50 percent (3.1.3), use the factor for the mold as determined in accordance with Section 6 (Calibration of Measure), MT-203.

METHOD C

8 Sample:

8.1 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of drying apparatus such that the temperature does not exceed 60° C (140° F). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.

8.2 Sieve an adequate quantity of the representative pulverized soil over the 3/4 in. (19.0 mm) sieve. Discard the coarse material if any, retained on the 3/4 in. (19.0 mm) sieve (Note 7).

Note 7 - If it is advisable to maintain the same percentage of coarse material (passing a 50 mm sieve and retained on a 4.75 mm sieve) in the moisture-density sample as in the original field sample, the material retained on the 19.0 mm sieve shall be replaced as follows: Sieve an adequate quantity of the representative pulverized soil over the 50 mm and 19.0 mm sieve. Weigh the material passing the 50 mm sieve and retained on the 19.0 mm sieve and replace it with an equal mass of material passing the 19.0 mm sieve and retained on the 4.75 mm sieve. Take the material for replacement from the remaining portion of the sample.

8.3 Select a representative sample, having a mass of approximately 12 lb. (5 kg) or more, of the soil prepared as described in 4.1 and 4.2.

9 Procedure:

9.1 Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately 4 percentage points below optimum moisture content.

9.2 Form a specimen by compacting the prepared soil in the 4 in. (102.60 mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5 in. (125 mm). Prior to compaction, place the loose soil into the mold and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose or fluffy state, using either the manual compaction rammer or a similar device having a face diameter of approximately 2 inches (50 mm). Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 12 in. (305 mm) above the elevation of the soil when a sleeve-type rammer is used, or from 12 in. (305 mm) above the approximate elevation of each finally compacted layer when a stationary mounted type rammer is used. During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation (Note 5).

9.2.1 Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge. Holes developed in the surface by removal of coarse material shall be patched with smaller size material. Weigh the mold and moist soil in pounds to the nearest 0.01 lb.; or weigh in kilograms to the nearest 5 grams. For molds conforming to tolerances given in Section 3.1.1, and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 30, and record the result as the wet density, W_1, in lb./ft.^{3}, of compacted soil. For molds conforming to tolerances given in Section 3.1.1 and masses recorded in kilograms, multiply the mass of the compacted specimen and mold, minus the mass of the mold, by 1060, and record the result as wet density, W_1, in kg/m^3, of compacted soil. For used molds out of tolerance by not more than 50 percent (3.1.3), use the factor for the mold as determined in accordance with Section 6 (Calibration of Measure), MT-203.

9 Procedure: (continued)

9.3 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material from one of the cut faces, weigh immediately, and dry in an oven at 110 ± 5° C (230 ± 9° F) for at least 12 hours, or to constant mass, to determine the moisture content. The moisture content sample shall weigh not less than 500 g.

9.4 Thoroughly break up the remainder of the material until it will pass a 3/4 in. (19.0 mm) sieve and 90 percent of the soil aggregations will pass a 3/4 in. (4.75 mm) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage points, and repeat the above procedure for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet mass, W_1, per cubic foot or cubic meter of compacted soil (Note 6).

METHOD D

10 Sample:

10.1 Select the representative sample in accordance with 7.3 except that it shall have a mass of approximately 25 lb. (11 kg).

11 Procedure:

11.1 Follow the same procedure as described for Method C in Section 8 except for the following. Form a specimen by compacting the prepared soil in the 6 in. (152.4 mm) mold (with collar attached) in three approximately equal layers to give a total compacted depth of about 5 in. (125 mm), each layer being compacted by 56 uniformly distributed blows from the rammer. For molds conforming to tolerances given in 3.1.2 and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 13.33, and record the results as the wet unit mass, W_1, in lb/ft³, of the compacted soil. For molds conforming to tolerances given in 3.1.2 and masses recorded in kilograms, multiply the mass of the compacted specimen and mold, minus the mass of the mold, by 471, and record the result as the wet unit mass, W_1, in kg/m³ of compacted soil. For used molds out of tolerance by not more than 50 percent (3.1.3), use the factor for the mold as determined in accordance with Section 6 (Calibration of Measure) MT-203.

CALCULATIONS AND REPORT

12 Calculations:

12.1 Calculate the moisture content and the dry unit mass of the soil as compacted for each trial, as follows:

$$w = \frac{A - B}{B - C} \times 100$$

and

$$W = \frac{W_1}{w + 100} \times 100$$

12 Calculations: (continued)

where:

w = percentage of moisture in the specimen, based on oven dry mass of soil.
A = mass of container and wet soil.
B = mass of container and dry soil.
C = mass of container.
W = dry mass, in pounds per cubic foot of compacted soil, or kilograms per cubic meter of compacted soil, and
W_1 = wet mass, in pounds, per cubic foot of compacted soil or kilograms per cubic meter of compacted soil.

13 Moisture-Density Relationship:

13.1 The calculation in 12.1 shall be made to determine the moisture content and corresponding oven-dry unit mass (density) in pounds per cubic foot or kilograms per cubic meter of the compacted samples. The oven-dry densities (unit weight) of the soil shall be plotted as ordinates and the corresponding moisture content as abscissas.

13.2 *Optimum Moisture Content*--When the densities and corresponding moisture contents for the soil have been determined and plotted as indicated in 13.1, it will be found that by connecting the plotted points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve shall be termed the "optimum moisture-content" of the soil under the above compaction.

13.1 The calculations in 12.1 shall be made to determine the moisture content and corresponding oven-dry unit mass (density) in pounds per cubic foot or kilograms per cubic meter of the compacted samples. The oven-dry densities (unit weight) of the soil shall be plotted as ordinates and the corresponding moisture content as abscissas.

13.2 *Optimum Moisture Content*--When the densities and corresponding moisture contents for the soil have been determined and plotted as indicated in 13.1, it will be found that by connecting the plotted points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve shall be termed the "optimum moisture-content" of the soil under the above compaction.

13.3 *Maximum Density*--The oven-dry density in pounds per cubic foot or kilograms per cubic meter of the soil at optimum moisture content shall be termed "maximum density" under the above compaction.

14 Report:

14.1 The report shall include the following:

14.1.1 The method used (Method A, B, C, or D),

14.1.2 The optimum moisture content, as a percentage, to the nearest whole number,

14.1.3 The maximum density in lbs. per cu. ft., to the nearest 0.1 lb/ft³ or in kilograms per cubic meter, the nearest 1 kg.,

14.1.4 In Methods C and D indicate if the material retained on the 19.0 mm sieve was removed or replaced.,

14.1.5 Type of face if other than 2 in. (50.8 mm) circular.

METHODS OF SAMPLING AND TESTING
MT 211-04
METHOD OF TEST FOR
MOISTURE-DENSITY RELATIONS OF SOIL-CEMENT MIXTURES
(Modified AASHTO T 134)

1 Scope:

1.1 This method covers procedures for determining the relationship between the moisture content and the density of soil-cement mixtures when compacted before cement hydration as prescribed.

1.2 A 1/30 cu. ft. (0.9 liter) mold and a 5.5 lb. (2.5 kg) rammer dropped from a height of 12 in. (305 mm) are used and two methods, depending on soil gradation, are covered as follows:

1.2.1 *Method A* - Using soil material passing the 4.75 mm sieve. This method shall be used when 100 percent of the soil sample passes the 4.75 mm sieve, Sections 4 and 5.

1.2.2 *Method B* - Using soil sample passing the 19.0 mm sieve. This method shall be used when part of the soil sample is retained on the 4.75 mm sieve, Sections 6 and 7.

2 Referenced Documents:

2.1 ***AASHTO:***
T 134 Moisture-Density Relations of Soil-Cement Mixtures

MT Manual:
MT-203 Unit Weight of Aggregate
MT-405 Wire Cloth Sieves for Testing Purposes

3 Apparatus:

3.1 *Molds* - The molds shall be solid-wall, metal cylinders manufactured with dimensions and capacities shown in 3.1.1. They shall have a detachable collar assembly approximately 2 3/4 in. (60 mm) in height, to permit preparation of compacted specimens of soil-cement mixtures of the desired weight and volume. The mold and collar assembly shall be so constructed that it can be fastened firmly to a detachable base plate made of the same material.

Note 1 - Alternate types of molds with capacities as stipulated herein may be used, provided the test results are correlated with those of the solid-wall mold on several soil types and the same moisture-density results are obtained. Records of such correlations shall be maintained and readily available for inspection when alternate types of molds are used.

3.1.1 A 4-inch mold having a capacity of 1/30 ± 0.0003 cu. ft. (944 ± 8.5 cm^3) with an internal diameter of 4.000 ± 0.016 in. (101.6 ± 0.4 mm) and a height of 4.584 ± 0.005 in. (116.4 ± 0.1 mm).

3.1.2 *Molds Out of Tolerance Due to Use* - A mold that fails to meet manufacturing tolerances after continued service may remain in use provided those tolerances are not exceeded by more than 50 percent; and the volume of the mold, calibrated in accordance with Sec 6 (Calibration of Measure) of MT-203, Unit Weight of Aggregate, is used in the calculations:

3.2 *Rammer:*

3.2.1 *Manually Operated* - Metal rammer having a flat circular face of 2.000 ± 0.001 in. (50.8 ± 0.127 mm) diameter, a wear tolerance of 0.005 (0.127 mm) and weighing 5.50 ± 0.02 lb. (2.495 ± 0.009 kg) (Note 2). The rammer shall be equipped with a suitable guide-sleeve to control the height of drop to a free fall of 12.00 ± 0.06 (or 1/16 in.) (304.8 ± 1.524 mm) above the elevation of the soil.

3 Apparatus: (continued)

The guide-sleeve shall have at least 4 vent holes, no smaller than 3/8 in. (9.5 mm) diameter spaced approximately 90 deg. apart and approximately 3/4 in. (19 mm) from each end, and shall provide sufficient clearance so the free fall of the rammer shaft and head is unrestricted.

3.2.2 *Mechanically Operated* - A metal rammer which is equipped with a device to control the height of drop to a free fall of 12.00 ± 0.06 (or 1/16 in.) (304.8 ± 1.524 mm) above the elevation of the soil and uniformly distributes such drops to the soil surface. The rammer shall have a flat circular face 2.000 ± 0.001 in. (50.8 ± 0.127 mm) in diameter, a wear tolerance of 0.005 (0.127 mm) and a manufactured mass of 5.50 ± 0.02 lb. (2.495 ± 0.009 kg) (Note 2).

Note 2 - The rammer apparatus shall be calibrated with several soil-cement mixtures and the mass of the rammer adjusted, if necessary, to give the same moisture-density results as with the manually operated rammer. It may be impractical to adjust the mechanical apparatus so the free fall is 12 in. (305 mm) each time the rammer is dropped, as with the manually operated rammer. To make the adjustment of free fall, the portion of loose soil to receive the initial blow should be slightly compressed with the rammer to establish the point of impact from which the 12 in. (305 mm) drop is determined. Subsequent blows on the layer of soil-cement may all be applied by dropping the rammer from a height of 12 in. (305 mm) above the initial-setting elevation, or when the mechanical apparatus is designed with a height adjustment for each blow, all subsequent blows should have a rammer free fall of 12 in. (305 mm) measured from the elevation of the soil as compacted by the previous blow.

3.2.3 *Rammer Face* - The circular face rammer shall be used but a sector face rammer may be used as an alternative provided the report shall indicate type of face used other than the 2 in. (50.8 mm) circular face and it shall have an area equal to that of the circular face rammer.

3.3 *Sample Extruder* - A jack, lever, frame, or other device adopted for the purpose of extruding compacted specimens from the mold.

3.4 *Balances and Scales* - A balance or scale of at least 25 lb. capacity having a sensitivity and readability to 0.01 lb., or a balance or scale having a capacity of approximately 11.5 kg. and a sensitivity and readability to 5 grams. Also, a balance of at least 1 kg capacity with a sensitivity and readability to 0.1 gram.

3.5 *Drying Oven* - A thermostatically controlled drying oven capable of maintaining a temperature of 110 ± 5° C (230 ± 9° F) for drying moisture samples.

3.6 *Straightedge* - A hardened steel straightedge at least 10 in. (254 mm) in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.01 in. per 10 in. (0.1 percent) of length within the portion used for trimming the soil (Note 3).

Note 3 - The beveled edge may be used for final trimming if the edge is true within a tolerance of 0.01 in. per 10 in. (0.1 percent) of length; however, with continued use, the cutting edge may become excessively worn and not suitable for trimming the soil to the level of the mold. The straightedge should not be so flexible that trimming the soil surface with the cutting edge will cause concave soil surface.

3.7 *Sieves* - 50, 19.0, 4.75 mm sieves conforming to the requirements of MT-405, Sieves for Testing Purposes.

3.8 *Mixing Tools* - Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

3.9 *Container* - A flat, round pan for moisture absorption by soil-cement mixtures about 12 in. (300 mm) in diameter and 2 in. (50 mm) deep.

3 **Apparatus:** (continued)

3.10 *Moisture Containers* - Suitable containers made of material resistant to corrosion and not subject to change in weight or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial weighing and to prevent absorption of moisture from the atmosphere following drying and before final weighing. One container is needed for each moisture content determination.

3.11 *Butcher Knife* - A butcher knife approximately 10 in. (250 mm) in length, for trimming the top of the specimens.

METHOD A. USING SOIL MATERIAL PASSING A 4.75 mm SIEVE

4 **Sample:**

4.1 Prepare the sample for testing by breaking up the soil aggregations to pass the 4.75 mm sieve in such a manner as to avoid reducing the natural size of the individual particles. When necessary, first dry the sample until it is friable under a trowel. Drying may be accomplished by air drying or by the use of drying apparatus such that the temperature of the sample does not exceed 60° C (140° F).

4.2 Select a representative sample weighing approximately 6 lb. (2.72 kg) or more, of the soil prepared as described in 4.1.

5 **Procedure:**

5.1 Add to the soil the required amount of cement conforming to AASHTO M 85, Specifications for Portland Cement, or AASHTO M 240, Blended Hydraulic Cements. Mix the cement and soil thoroughly to a uniform color. When needed, add sufficient potable water to dampen the mixture to approximately four to six percentage points below the estimated optimum moisture content and mix thoroughly. At this moisture content, plastic soils, tightly squeezed in the palm of the hand, will form a cast that will fracture with only slight pressure applied by the thumb and fingertips; nonplastic soils will bulk noticeably. When the soil is a heavy-textured clayey material, compact the mixture of soil, cement, and water in the container to a depth of about 2 in. (50 mm) using the rammer described in 3.2.1 or a similar hand tamper. Cover, and allow to stand for not less than 5 min. but not more than 10 min. to aid dispersion of the moisture and to permit more complete absorption by the soil-cement. After the absorption period thoroughly break up the mixture, without reducing the natural size of individual particles, until it will pass a 4.75 mm sieve and then remix.

5.2 Form a specimen by compacting the prepared soil-cement mixture in the mold, with the collar attached, in three equal layers so as to give a total compacted depth of about 5 in. (127 mm). Compact each layer by 25 blows from the rammer dropping free from a height of 12 in. (305 mm) above the elevation of the soil-cement when a sleeve-type rammer is used, or from 12 in. (305 mm) above the approximate elevation of each finally compacted layer when a stationary-mounted type rammer is used. The blows shall be uniformly distributed over the surface of the layer being compacted. During compaction, the mold shall rest on a uniform, rigid foundation (Note 4). Following compaction, remove the extension collar, carefully trim the compacted mixture even with the top of the mold by means of the knife and straightedge, and weigh to the nearest 0.01 lb. (0.004 kg). Multiply the mass of the compacted specimen and mold, minus the mass of the mold by 30; record the results as the wet mass per cubic foot (kg/m³) W_1 of the compacted soil-cement mixture.

5 Procedure: (continued)

Note 4 - Each of the following has been found to be a satisfactory base on which to rest the mold during compaction of the soil; a block of concrete weighing not less than 200 lb. (90.8 kg), supported by a relatively stable foundation; a sound concrete floor; and for field application, such surfaces as found in concrete box culverts, bridges and pavements.

5.3 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material, weighing not less than 100 grams, from the full height of one of the cut faces, weigh immediately, and dry in an oven at 230 ± 9°F (110 ± 5°C) for at least 12 hours or to constant mass. Calculate the moisture content of the sample as directed in Section 7. Record the results as the moisture content, w, of the compacted soil-cement mixture.

5.4 Thoroughly break up the remaining portion of the molded specimen until it will pass a 4.75 mm sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amount to increase the moisture content of the soil-cement mixture by one or two percentage points, mix, and repeat the procedure given in 5.2 and 5.3 for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet mass per cubic foot (kg/m^3) W_t of the compacted soil-cement mixture.

Note 5 - This procedure has been found satisfactory in most cases. However, in instances where the soil material is fragile in character and will reduce significantly in grain size due to repeated compaction, a separate and new sample shall be used for each moisture-density determination.

METHOD B. USING MATERIAL PASSING A 19.0 mm SIEVE

6 Sample:

6.1 Prepare the sample for testing by segregating the aggregate retained on a 4.75 mm sieve and breaking up the remaining soil aggregations to pass the 4.75 mm sieve in such a manner as to avoid reducing the natural size of individual particles. When necessary, first dry the sample until it is friable under a trowel. Drying may be accomplished by air drying or by the use of drying apparatus such that the temperature of the sample does not exceed 60° C (140° F).

6.2 Sieve the prepared soil over the 75 mm (Note 6), 19.0 mm, and 4.75 mm sieves. Discard the material retained on the 75 mm sieve. Determine the percentage of material, by oven-dry mass, retained on the 19.0 mm and 4.75 mm sieves. Saturate the aggregate passing the 19.0 mm sieve and retained on the 4.75 mm sieve by soaking in potable water; surface-dry the material as required for later testing.

Note 6 - Most soil-cement construction specifications covering soil gradation limit maximum size material to 75 mm (3 in.) or less.

6.3 Select and maintain separate representative samples of soil passing the 4.75 mm sieve and of saturated, surface-dry aggregate passing the 19.0 mm sieve and retained on the 4.75 mm sieve so that the total sample will weigh approximately 11 lb. (5 kg) or more. The percentage, by oven-dry mass, of aggregate passing the 19.0 mm sieve and retained on the 4.75 mm sieve shall be the same as the percentage passing the 75 mm sieve and retained on the 4.75 mm sieve in the original sample.

7 Procedure:

7.1 Add to the portion of the soil sample passing the 4.75 mm sieve the amount of cement conforming to AASHTO M 85, Specifications for Portland Cement, AASHTO M 240. Blended Hydraulic Cement required for the total sample specified in 5.1. Mix the cement and soil thoroughly to a uniform color. When needed, add water to this soil-cement mixture and facilitate moisture

7 **Procedure:** (continued)

dispersion as described for Method A in 4.1. After this preparation, add the saturated, surface-dry aggregate to the soil-cement mixture passing the 4.75 mm sieve and mix thoroughly.

7.2 Form a specimen by compacting the prepared soil-cement mixture in the mod (with the collar attached) and trim and weigh the compacted specimen as described for Method A in 5.2. During the trimming operation remove all particles that extend above the top level of the mold. Correct all irregularities in the surface by hand-tamping fine material into these irregularities and leveling the specimen again with the straightedge. Multiply the mass of the compacted specimen and mold, minus the mass of the mold, by 30; record the result as the wet mass per cubic foot, W_1 of the compacted soil-cement mixture.

7.3 Remove the material from the mold and take a sample for determining the moisture content as described for Method A in 5.3, except that the moisture sample shall weigh not less than 500g. Record the result as the moisture content *w*, of the compacted soil-cement mixture.

7.4 Thoroughly break up the remainder of the material as before until it will pass a 19.0 mm sieve and at least 90 percent of the soil particles smaller than a 4.75 mm sieve will pass a 4.75 mm sieve, as judged by eye, and add all other material remaining after obtaining the moisture sample. Add sufficient water to increase the moisture content of the soil-cement mixture by one or two percentage points, mix, and repeat the procedure described in 7.2 and 7.3 for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet mass per cubic foot (kg/m^3) W_1 of the compacted soil-cement mixture (Note 5).

CALCULATIONS AND REPORTS

8 **Calculations:**

8.1 Calculate the moisture content and oven-dry mass per cubic foot of the compacted soil-cement mixture for each trial as follows:

$$w = \frac{A - B}{B - C} \times 100$$

$$W = \frac{W_1}{w + 100} \times 100$$

where:

w = percentage of moisture in the specimen,
A = mass of moisture can and wet soil-cement,
B = mass of moisture can and oven-dry soil cement,
C = mass of moisture can,
W = oven-dry mass in pounds per cubic foot (kg/m^3) of compacted soil-cement, and
W_1 = wet mass in pounds per cubic foot (kg/m^3) of compacted soil-cement.

9 **Moisture-Density Relationship:**

9.1 The calculations in Section 8 shall be made to determine the moisture content and corresponding oven-dry mass pounds per cubic foot (kg/m^3) (density) for each of the compacted soil-cement samples. The oven-dry mass, pounds per cubic foot (kg/m^3) (densities) of the soil-cement mixture shall be plotted as ordinates and the corresponding moisture contents as abscissas.

9 Moisture-Density Relationship: (continued)

9.2 *Optimum Moisture Content* - When the densities and corresponding moisture contents for the soil-cement mixture have been determined and plotted as indicated in 9.1, it will be found that by connecting the plotted points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve shall be termed the "Optimum moisture content" of the soil-cement mixture under the compaction prescribed in these methods.

9.3 *Maximum Density* - The oven-dry mass, pounds per cubic foot (kg/m^3) of the soil cement mixture at "optimum moisture content" shall be termed "maximum density" under the compaction prescribed in these methods.

10 Report:

10.1 The report shall include the following:

10.1.1 The method used (Method A or B).

10.1.2 The optimum moisture content, and

10.1.3 The maximum density.

METHODS OF SAMPLING AND TESTING
MT 212-04
METHOD OF TEST FOR
DETERMINATION OF MOISTURE AND DENSITY OF IN-PLACE MATERIALS

1 Scope:

1.1 This method of test is intended as a means of determining the moisture and/or density of in-place materials, either in the natural state or after compaction.

1.2 In-place moisture and density determinations shall be made by the use of nuclear density/moisture equipment. Moisture may be determined by oven drying or by the calcium carbide method, MT-215.

2 Referenced Documents:

2.1 ***MT Manual:***
MT-215 Moisture Content by Calcium Carbide Method
MT-313 Procedure for Comparing Nuclear Gauge to Core Densities of Bituminous Paving Mixtures

2 Types of Equipment:

2.1 The types of equipment being used at the present time are:

2.1.1 A portable nuclear moisture/density gauge containing radioactive sources, electronics and rechargeable batteries

2.1.2 Standard Count Reference Block

2.1.3 AC Charger 115v/60Hz and DC Adapter 12v negative ground

2.1.4 Transport case designed and labeled for each specific gauge

2.1.5 Scraper Plate/Drill Rod Guide

2.1.6 Drill Rod and Drill Rod Extractor

2.1.7 Operators Manual and Gauge Booklet

2.2 The nuclear moisture/density gauges are calibrated by the Montana Department of Transportation for testing density of PCC and AC pavements. The gauges are also calibrated for both density and moisture of most soils and soil aggregate mixtures. The calibrations are stored electronically within the gauge.

2.3 Modes of density operation are backscatter and direct transmission (see Operator Manual). Direct transmission reduces surface roughness error and tests a larger volume of material resulting in increased precision. For these reasons, direct transmission is **required** whenever possible when testing soils and base gravels. Moisture may be tested with the source rod in any position.

3 Operating Instructions:

3.1 A manufacturer's instructional manual is furnished with each nuclear device and must be consulted for operational procedures. These procedures vary between gauges and must be

followed carefully.

3 Operating Instructions: (continued)

3.2 NUCLEAR GAUGES SHALL ONLY BE DISTRIBUTED TO PERSONNEL WHO HAVE RECEIVED THE REQUIRED 8 HOUR RADIATION SAFETY AND NUCLEAR GAUGE OPERATION COURSE. Upon successful completion of this training, the operator will be furnished a certification card which signifies that she/he is fully qualified to operate nuclear gauges. Additionally, gauge operators must attend a 2 to 4 hour refresher course at intervals not to exceed two years. This training will be provided by MDT.

3.3 District Materials Supervisors must ensure that each gauge operator has completed an approved operator training course, that their card is up to date and in their possession, and that a radiation monitoring device is properly utilized when handling nuclear gauges.

3.4 Some instructional procedures, which should be emphasized, are:

3.4.1 The operator should be very familiar with the Operator's Instruction Manual.

3.4.2 Always be aware of battery charge status and follow battery care instructions in Operator's Manual.

3.4.3 The gauge electronics must be turned on to warm up for a minimum of 15 minutes before taking the daily standard count or testing.

3.4.4 Standard counts shall be taken and recorded each day that gauges are put into use.

3.4.5 If the daily standard counts are more than 1% for density or 2% for moisture from the average of the previous four counts, procedures should be thoroughly examined and the counts taken again. If these counts also fail, problems with the gauge or procedure are indicated and the appropriate District or Area Laboratory should be contacted.

3.4.6 A Stability Test shall be performed:

3.4.6.1 Whenever the accuracy of the gauge is in doubt

3.4.6.2 Before gauge-core correlations

3.4.6.3 At least every two weeks during periods of routine testing.

STABILITY TEST

20 One-Minute Standard Counts
Use Actual Gauge Reading

3.4.6.4 Compute Average, (AVG.)

3.4.6.5 Compute Square Root of Avg., $\sqrt{}$(AVG.)

3.4.6.6 Compute Standard Deviation, (ST.DEV.)

3.4.6.7 Compute Stability Ratio, $\frac{\text{ST.DEV}}{\sqrt{\text{AVG.}}}$ = Stability Ratio

3 Operating Instructions: (continued)

PASSING RATIOS:

	Moisture	Density
Model 3411-B	0.18-0.35	0.18-0.35
Model 3440	0.18-0.35	0.18-0.35

Note - If the ratio falls outside of the indicated ranges, procedures should be checked and the stability test taken again. If another failure occurs, contact the appropriate District or Area Lab.

3.4.7 Shovel, trowel or scraper and straightedge must be used to prepare the test site - **DO NOT USE THE STANDARD TEST BLOCK.**

3.4.8 Use minus No. 30 sieve size dry sand for seating the gauge base. Whenever available, this sand should be native to the project material.

3.4.9 A thin layer of sand should remain between the bottom of the gauge and the ground surface. Any unusual voids or air gaps can cause considerable decrease in density readings.

3.4.10 When testing soils, base gravel, pulverized plant mix materials, cement treated aggregates for acceptance, take two, one-minute counts in the direct transmission mode. Take the first count and record the moisture and density counts. Rotate the gauge 180° around the source rod and take the second count and record the moisture and density counts. The average of the two counts will constitute a test. A valid test consists of density counts in both gauge positions that are within 50 kg/m³ (3 lb/ft³).

3.4.11 When testing plant mix for density acceptance, four (one minute) tests at 90° intervals as in the pattern defined in MT-313 will be performed. All four one minute tests must be within 40 kg/m³ (2.5 lb/ft³). The average of the four tests will be the final test result.

3.4.12 Periodic comparison checks should be made using conventional methods.

4 Calculations:

4.1 Use Lab. Form No. 1000A for recording field determinations with Nuclear Devices. These forms are supplied through the Purchasing Services Bureau (Stores) upon request.

4.1.1 Wet density, dry density, and moisture, all in pounds per cubic foot, can be read directly from the gauge scales. Percent moisture can also be read directly.

4.1.2 $\frac{\text{Field Dry Density (lbs/ft}^3\text{)}}{\text{Proctor Dry Density}} \times 100 = \%$ compaction

4.1.3 $\frac{\text{Field Wet Density (lbs/ft}^3\text{)}}{\text{Marshall Density}} \times 100 = \%$ compaction

4.1.4 Compare field moisture to optimum moisture from the Proctor determination.

4.1.5 If problems occur on thin lift plant mix overlays, refer to pages 7 and 8 of this test procedure.

5 Radiological Considerations:

5.1 The use of nuclear devices is licensed by the Nuclear Regulatory Commission (NRC). The NRC requires a radiation monitoring system for individuals. They also require the leak testing of nuclear gauges every six months.

5.2 The Materials Bureau has subscribed to a quarterly TLD badge service. We distribute these badges to all District Materials Supervisors and collect them once a quarter. The District Materials Supervisors issue these badges and instruct each nuclear gauge operator on the following:

5.2.1 Each nuclear gauge operator must wear a TLD badge attached to the front of his clothing or belt at waist level.

5.2.2 These TLD badges must not be transferred from one operator to another.

5.2.3 Whenever badges are not being worn, they must be stored at least 30 feet from nuclear gauges, out of direct sunlight, and away from excessive heat or dampness. **BADGES LEFT NEAR GAUGES ARE ESPECIALLY SUSCEPTIBLE TO UNFOUNDED HIGH READINGS.**

5.2.4 Whenever a TLD badge has a high reading, the individual to whom the badge was issued will be notified and must fill out a report and submit it to the Materials Bureau within five days. It is important that all facts and details be presented accurately and conscientiously including diagrams, distances and times. Statements from supervisors and witnesses are also valuable.

5.2.5 The District Materials Supervisor will keep an up-to-date record consisting of the individual's name, the date the badge was issued, the individual's age, the serial number of the gauge they are using, and the project to which the gauge is assigned. This information, along with the TLD badges will be mailed to the Materials Bureau within ten days after the end of the quarter.

5.2.6 An Occupational Radiation History form (NRC Form 4) must be completed by every employee operating a nuclear gauge. The completed form must be sent to the Materials Bureau.

5.2.7 The leak testing of all nuclear gauges will be performed by personnel in the Materials Bureau or other individuals designated by the Radiation Safety Officer to perform such tests. An up-to-date record of the results of these tests shall also be maintained by the Materials Bureau.

6 NRC Licenses and Documents:

6.1 All personnel engaged in activities licensed by the NRC can examine the following documents at the Materials Bureau in Helena.

6.1.1 Publication 10 CFR-19, Notices, Instructions, and Reports to Workers and Inspectors.

6.1.2 Publication 10 CFR-20, Standards for Protection Against Radiation.

6.1.3 NCR License No. 25-11498-01, including all conditions and incorporated documents.

6.1.4 Operating procedures applicable to licensed activities.

6.2 A notice giving the location of the above documents will be inserted in the nuclear gauge operator's manual or posted in the shipping container. This notice and a map showing the location and telephone number of the regional offices of the NRC will be posted on the bulletin boards or other conspicuous places in each district laboratory and area laboratory. Montana is located in Region IV, telephone (817)860-8100.

6 NRC Licenses and Documents: (continued)

6.3 The District Materials Supervisors are responsible to see that each gauge operator has completed training in radiation safety and nuclear gauge operations. Proper storage, transporting, and distribution within the districts is also a part of this responsibility.

6.4 Inspections will be conducted by the Materials Bureau to verify compliance with the requirements of the license.

7 Transportation, Storage and Maintenance:

7.1 These instruments require careful handling. The vehicle in which they are transported should be capable of keeping them dry and provide complete security from unauthorized personnel. It should also be equipped with a carrying rack to which the instrument cases can be strapped and locked. This is a precision instrument designed to give many years of good service providing it has proper care.

7.2 Requirements for nuclear gauge storage.

7.2.1 Storage areas are to be locked and posted with radiation caution signs.

7.2.2 When the equipment is not being used, it should be stored in a separate dry room or garage. The temperature in the storage area should be above freezing and the batteries in the device should be fully charged. Never store a device in an area where personnel are working or will be working. Radiation caution signs shall be posted at the entrance door of any storage area.

7.2.3 Radiation levels surrounding the storage area shall not exceed two millirems per hour. To help ensure low radiation levels outside the storage area, a gauge should be stored as near the center of the room as practical. Gauges should not be stored above, below or adjacent to a work area. The best way to assure radiation safety is to limit the number of gauges in a storage area. The largest number of gauges to be stored in one area is determined by the outside radiation level which shall not exceed 2 millirems per hour. The Materials Bureau in Helena shall be called to check the outside area to see if the radiation levels are acceptable.

7.2.4 Store the gauge fully charged. Battery charging during storage is not necessary but gauges should be given a full charge prior to initial use at the beginning of the construction season.

7.3 *Maintaining the Gauge:*

7.3.1 The Materials Bureau should be notified immediately when any breakdowns occur. It will be decided at that time whether the gauge should be sent to the Materials Bureau for repairs.

7.3.2 Clean and maintain the gauge regularly as recommended in the Operator's Manual.

7.4 The Nuclear Gauge Transport paper shall be kept with the nuclear gauge at all times. When transporting a gauge, the certification shall be filled out, visible and within reach of the driver.

8 Theory of Operation:

8.1 For theory of operation and other detailed descriptions, consult the manufacturer's manual for the particular model gauge that you are using.

METHODS OF SAMPLING AND TESTING
MT 213-04
METHOD OF TEST FOR PLASTIC FINES IN GRADED AGGREGATES AND SOILS BY USE OF THE SAND EQUIVALENT TEST
(Modified AASHTO T 176)

1 Scope:

1.1 This test is intended to serve as a rapid field test to show the relative proportions of fine dust or claylike material in soils or graded aggregates.

1.2 The following applies to all specified limits in this standard: For the purpose of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value.

2 Referenced Documents:

2.1 ***AASHTO:***
T 176 Plastic Fines in Graded Aggregates and Soils by Use of the Sand Equivalent Test

3 Apparatus:

3.1 A graduated plastic cylinder, rubber stopper, irrigator tube, weighted foot assembly, and siphon assembly, all conforming to their respective specifications and dimensions shown in Figure 1. Fit the siphon assembly to a 1 gal. (4 liter) bottle of working calcium chloride solution (see 2.8) placed on a shelf 36 ± 1 in. (915 ± 25 mm) above the work surface. In lieu of the specified 1 gal. (4 liter) bottle, a glass or plastic vat having a larger capacity may be used providing the liquid level of the working solution is maintained between 36 and 46 inches (915 to 1,170 mm) above the work surface.

Note 1 - An older model of weighted foot assembly has a guide cap that fits over the upper end of the graduated cylinder and centers the rod in the cylinder, and the foot of the assembly has a conical upper surface and three centering screws to center it loosely in the cylinder. The older model does not have the sand reading indicator affixed to the rod (Figure 1), but a slot in the centering screws of the weighted foot is used to indicate the sand reading. Apparatus with the sand reading indicator (Figure 1) is preferred for testing clayey materials.

3.2 A 3 oz. (85 ml) tinned box approximately 2¼ in. (57 mm) in diameter, with Gill style cover and having a capacity of 85 ± 5 ml.

3.3 A wide-mouthed funnel approximately 4 in. (100 mm) in diameter at the mouth.

3.4 A clock or watch reading in minutes and seconds.

3.5 A mechanical shaker as shown in Figure 3, having a throw of 8 ± 0.04 in. (203.2 ± 1.02 mm), and operating at 175 ± 2 cycles per minute (2.92 ± 0.03 Hz) (Note 2). Prior to use, fasten the mechanical sand equivalent shaker securely to a firm and level mount.

3.6 A manually operated shaker as shown in Figure 4, capable of producing an oscillating motion at the rate of 100 complete cycles in 45 ± 5 s, with a hand-assisted half stroke length of 5.0 ± 0.2 in. (127.00 ± 5.08 mm). The shaker shall be fastened securely to a firm and level mount by bolts or clamps if a large number of determinations are to be made.

Note 2 - The mechanical shaker shall be used when performing referee sand equivalent determinations. Either the mechanical or manually operated shaker should be used in lieu of the hand method whenever possible.

3 Apparatus: (continued)

3.7 Stock calcium chloride solution: Prepare the stock calcium chloride solution with the following:

454 g (1 lb.) technical grade anhydrous calcium chloride
2.050 g (1.640 ml.) USP glycerine
47 g (45 ml) formaldehyde (40 percent by volume solution)

3.7.1 Dissolve the calcium chloride in ½ gal. (1.89 liters) of distilled or demineralized water. Cool the solution, then filter it through Whatman No. 12 or equivalent filter paper. Add the glycerine and formaldehyde to the filtered solution, mix well, and dilute to 1 gal. (3.79 liters) with distilled or demineralized water.

3.8 Working calcium chloride solution: Prepare the working calcium chloride by diluting one measuring tin fill (85 ± 5 ml.) of the stock calcium chloride solution to 1 gal. (3.79 liters) with water. Use distilled or demineralized water for the normal preparation of the working solution. However, if it is determined that the local tap water is of such purity that it does not affect the test results, it is permissible to use in lieu of distilled or demineralized water except in the event of dispute.

3.9 A straightedge or spatula, suitable for striking off the excess soil from the tin measure.

3.10 A thermostatically controlled drying oven capable of maintaining a temperature of 110 ± 5° C (230 ± 9° F).

4 Control:

4.1 The temperature of the working solution should be maintained at 22 ± 3° C (72 ± 5° F) during the performance of this test. If field conditions preclude the maintenance of the temperature range, frequent referee samples should be submitted to a laboratory where proper temperature control is possible. It is also possible to establish temperature correction curves for each material being tested where proper temperature control is not possible. However, no general correction curve should be utilized for several materials even within a narrow range of sand equivalent values. Samples that meet the minimums and equivalent requirement at a working solution temperature below the recommended range need not be subject to referee testing.

TS-1a T 176-2 AASHTO

FIGURE 1 Sand Equivalent Test Apparatus

5 Sample Preparation:

5.1 The sand equivalent test shall be performed on soils or graded aggregate materials passing the 4.75 mm (No. 4) sieve. All aggregations of fine-grained soil material shall be pulverized to pass the 4.75 mm sieve, and all fines shall be cleaned from the particles retained on the 4.75 mm sieve and included with the material passing the 4.75 mm sieve.

5.2 Split or quarter enough of the original sample to yield slightly more than four 3-oz. (85 ml.) tin measures of material passing the 4.75 mm sieve. Use extreme care to obtain a truly representative portion of the original sample (Note 3).

Note 3 - Experiments show that as the amount of material being reduced by splitting or quartering is decreased, the accuracy of providing representative portions is reduced. It is imperative that the sample be split or quartered carefully. When it appears necessary, dampen the material before splitting or quartering, to avoid segregation or loss of fines.

5.3 Prepare the desired number of test samples by one of the following methods:

5.3.1 *Alternate Method No. 1 - Air Dry.*

5.3.1.1 Split or quarter enough material from the passing 4.75 portion to fill the 3 oz. (85 ml) tin measure so it is slightly rounded above the brim. While filling the measure, tap the bottom edge of the tin on the work table or other hard surface to cause consolidation of the material and allow the maximum amount to be placed in the tin. Strike off the tin measure level full with a spatula or straightedge.

5.3.2 *Alternate Method No. 2 - Pre-Wet.*

5.3.2.1 The sample must be in the proper moisture condition to achieve reliable results. This condition is determined by tightly squeezing a small portion of the thoroughly mixed sample in the palm of the hand. If the cast that is formed permits careful handling without breaking, the correct moisture range has been obtained. If the material is too dry, the cast will crumble and it will be necessary to add water and remix and retest until the material forms a cast. If the material shows any free water, it is too wet to test and must be drained and air dried, mixing it frequently to insure uniformity. This overly wet material will form a good cast when checked initially, so the drying process should continue until a squeeze check on the drying material gives a cast which is more fragile and delicate to handle than the original. If the moisture content of the original sample prepared in 5.2 is within the limits described above, the test sample may be obtained immediately. If the moisture content is altered to meet these limits, the altered sample should be placed in a pan, covered with a lid or with a damp cloth which does not touch the material, and allowed to stand for a minimum of 15 minutes.

5.3.2.2 After the minimum 15-minute tempering period, place the sample on the splitting cloth and mix by alternately lifting each corner of the cloth and pulling it over the sample toward the diagonally opposite corner, causing the material to be rolled. When the material appears homogeneous, finish the mixing with the sample in a pile near the center of the cloth.

5.3.2.3 Fill the 3 oz. (85 ml) tin measure by pushing it through the base of the pile while exerting pressure with the hand against the pile on the side opposite the measure. As the tin is moved through the pile, hold enough pressure with the hand to cause the material to fill the tin to overflowing. Press firmly with the palm of the hand, compacting the material and allowing the maximum amount to be placed in the tin. Strike off the tin measure level full with a spatula or straightedge.

5 Sample Preparation: (continued)

Note 4 - Moist test specimens produce lower sand equivalent values than the corresponding over-dry specimens with almost no exceptions, therefore, if a dual specification encompassing both the wet and dry methods of sample preparation is utilized, it will be necessary to determine the appropriate correction for each material since a standard correction does not appear possible. Either method can be employed with equal confidence, however.

5.3.3 Referee Method (Mechanical Shaker) - *Obtain the 3 oz. (85 ml) tin measure of material by one of the alternate methods, 5.3.1 or 5.3.2, above, then dry the test sample to constant mass at 110 ± 5° C (230 ± 9° F), and cool to room temperature before testing.*

6 Procedure:

6.1 Siphon 4 ± 0.1 in. (101.6 ± 2.5 ml) of working calcium chloride solution into the plastic cylinder. Pour the prepared test sample from the measuring tin into the plastic cylinder using the funnel to avoid spillage. Tap the bottom of the cylinder sharply on the heel of the hand several times to release air bubbles and to promote thorough wetting of the sample.

6.2 Allow the wetting sample to stand undisturbed for 10 ± 1 minutes. At the end of the 10-minute soaking period, stopper the cylinder, then loosen the material from the bottom by partially inverting the cylinder and shaking it simultaneously.

6.3 After loosening the material from the bottom of the cylinder, shake the cylinder and contents by any one of the following methods:

6.3.1 *Mechanical Shaker Method (Referee Method)* - Place the stoppered cylinder in the mechanical sand equivalent shaker, set the timer, and allow the machine to shake the cylinder and contents for 45 ± seconds.

6.3.2 *Manual Shaker Method* - Secure the stoppered cylinder in the three spring clamps on the carriage of the hand operated sand equivalent shaker and reset the stroke counter to zero. Stand directly in front of the shaker and force the pointer to the stroke limit marker painted on the backboard by applying an abrupt horizontal thrust to the upper portion of the right hand spring steel strap. Then remove the hand from the strap and allow the spring action of the straps to move the carriage and cylinder in the opposite direction without assistance or hindrance. Apply enough force to the right hand spring steel strap during the thrust portion of each stroke to move the pointer to the stroke limit marker by pushing against the strap with the ends of the fingers to maintain a smooth oscillating motion. The center of the stroke limit marker is positioned to provide the proper stroke length and its width provides the maximum allowable limits of variation. The proper shaking action is accomplished only when the tip of the pointer reverses direction within the marker limits. Proper shaking action can best be maintained by using only the forearm and wrist action to propel the shaker. Continue the shaking action for 100 strokes.

6.3.3 *Hand Method* - Hold the cylinder in a horizontal position as illustrated in Figure 7 and shake it vigorously in a horizontal linear motion from end to end. Shake the cylinder 90 cycles in approximately 30 seconds using a throw of 9 ± 1 in. (229 ± 25 mm). A cycle is defined as a complete back and forth motion. To properly shake the cylinder at this speed, it will be necessary for the operator to shake with the forearms only, relaxing the body and shoulders.

6.4 Following the shaking operation, set the cylinder upright on the work table and remove the stopper.

6.5 *Irrigation Procedure* - Insert the irrigator tube in the cylinder and rinse material from the cylinder walls as the irrigator is lowered. Force the irrigator through the material to the bottom of the cylinder by applying a gentle stabbing and twisting action

6 Procedure: (continued)

while the working solution flows from the irrigator tip. This flushes the fine material into suspension above the coarser sand particles. Continue to apply the stabbing and twisting action while flushing the fines upward until the cylinder is filled to the 15 in. (381 mm) mark. Then raise the irrigator slowly without shutting off the flow so that the liquid level is maintained at about 15 in. (381 mm) while the irrigator is being withdrawn. Regulate the flow just before the irrigator is entirely withdrawn and adjust the final level to 15 in. (381 mm).

6.6 Allow the cylinder and contents to stand undisturbed to 20 minutes ± 15 seconds. Start the timing immediately after withdrawing the irrigator tube.

6.7 At the end of the 20-minute sedimentation period, read and record the level of the top of the clay suspension. This is referred to as the "clay reading." If no clear line of demarcation has formed at the end of the specified 20-minute sedimentation period, allow the sample to stand undisturbed until a clay reading can be obtained, then immediately read and record the level of the top of the clay suspension and the total sedimentation time. If the total sedimentation time exceeds 30 minutes, rerun the test using three individual samples of the same material. Read and record the clay column height of that sample requiring the shortest sedimentation period only.

6.8 After the clay reading has been taken, the "sand reading" shall be obtained by one of the following methods:

6.8.1 When using the weighted foot assembly having the sand indicator on the rod of the assembly place the assembly over the cylinder and gently lower the assembly toward the sand. Do not allow the indicator to hit the mouth of the cylinder as the assembly is being lowered. As the weighted foot comes to rest on the sand, tip the assembly toward the graduations on the cylinder until the indicator touches the inside of the cylinder. Subtract 10 inches (254 mm) from the level indicated by the extreme top edge of the indicator and record this value as the "sand reading."

6.8.2 If an older model weighted foot assembly having centering screws is used, keep one of the centering screws in contact with the cylinder wall near the graduations so that it can be seen at all times while the assembly is being lowered. When the weighted foot has come to rest on the sand, read the level of the centering screw and record this value as the "sand reading."

6.9 If clay or sand readings fall between 0.1 in. (2.5 mm) graduations, record the level of the higher graduation as the reading. For example, a clay reading of 7.95 would be recorded as 8.0 and a sand reading of 3.22 would be recorded as 3.3.

Note 5 - Samples obtained from aggregate proposed for use in hot asphalt paving mixtures shall be prepared by oven-drying if acceptance of the material is based on tests on material that has passed through a hot plant drier.

7 Calculations:

7.1 Calculate the sand equivalent (SE) to the nearest 0.1 using the following formula:

$$SE = \frac{\text{Sand Reading}}{\text{Clay Reading}} \times 100$$

7 **Calculations:** (continued)

7.2 If the calculated sand equivalent is not a whole number, report it as the next higher whole number, as in the following example:

$$SE = \frac{3.3}{8} \times 100 = 41.25,$$

which is reported as 42.

7.3 If it is desired to average a series of sand equivalent values, average the whole number values determined as described above. If the average of these values is not a whole number, raise it to the next higher whole number, as in the following example:

Calculated SE values: 41.2, 43.8, 40.9

After raising each to the next higher whole number, they become: 42, 44, 41

The average of these values is then determined:

$$AVG \frac{42 + 44 + 41}{3} = 42.3$$

7.3.1 Since the average value is not a whole number, it is raised to the next higher whole number and the reported averages and equivalent value is reported as "43."

8 **Precautions:**

8.1 Perform the test in a location free of vibrations; vibrations may cause the suspended material to settle at a rate greater than normal.

8.2 Do not expose the plastic cylinders to direct sunlight any more than is necessary.

8.3 Removal of Organic Growth: Occasionally it may be necessary to remove an organic growth from the working calcium chloride solution container and from the inside of the flexible tubing and irrigator tube. This organic material can easily be seen as a slimy substance in the solution. To remove this growth, prepare a cleaning solvent by diluting sodium hypochlorite with an equal quantity of water (see Note 6). Fill the solution container with the prepared cleaning solvent, allow about a liter of the cleaning solvent to flow through the siphon assembly and irrigator tube, then place the pinch clamp on the end of the tubing to cut off the flow of solvent and to hold the solvent in the tube.

Note 6 - Chlorox or its equivalent has been found satisfactory for this purpose.

Refill the container and allow to stand overnight. After soaking, allow the cleaning solvent to flow out through the siphon assembly and irrigator tube. Remove the siphon assembly from the solution container and rinse both with clear water. The irrigator tube and siphon assembly can be rinsed easily by attaching a hose between the tip of the irrigator tube and water faucet and backwashing fresh water through the tube.

8.4 Occasionally the holes in the tip of the irrigator tube may become clogged by a particle of sand. If the obstruction cannot be freed by any other method, use a pin or other sharp object to force it out, using extreme care not to enlarge the size of the opening.

9 Operator Qualifications:

9.1 Before an operator is allowed to perform the sand equivalent test by either the manual method or the hand method, he must meet certain qualification requirements for that method. Although the qualification requirements are identical for both methods, an operator shall be permitted to use only that method for which he has qualified.

9.1.1 The operator must be capable of obtaining consistent sand equivalent test results on representative samples of any given material when the test is performed in accordance with the prescribed procedure for that particular method. An operator's test results are considered to be consistent if the individual results of three tests performed by him on representative samples of any given material do not vary by more than ± 4 points from the average of these tests.

8.1.2 The average of three tests by an operator on any given material must correspond within ± 4 points with the average of three tests on the same material when tested using the mechanical shaker method (Referee Method).

9.2 If an operator is not capable of obtaining consistent results with the manual shaker method, or if his results do not agree with results obtained by the mechanical shaker method, he is not to perform the sand equivalent test using the manual shaker until he has perfected his technique sufficiently to bring his test results into the specified limits without adjusting the required number of cycles.

8.3 If an operator is capable of obtaining consistent results when qualifying for the hand method, but the average of his results does not agree within the prescribed limits of the average of three results by the mechanical shaker method, he shall adjust the number of shaking cycles sufficiently to cause his results to agree with those by the mechanical shaker method. Determine the required adjustment in the shaking cycles by the following method:

9.3.1 Estimate the adjusted number of shaking cycles required. Increase the number of cycles to obtain a lower sand equivalent test result or decrease the number of cycles to obtain a higher sand equivalent test result. Perform three tests at the adjusted number of cycles. Strive to maintain the prescribed shaking rate of 180 cycles per minute. Compare the average of the three test results using the adjusted number of strokes with the average obtained by the mechanical shaker method. If necessary, readjust the number of shaking cycles until the average result of three tests at the adjusted number of cycles is within ± 4 points of the average obtained by the mechanical shaker.

9.4 The ± 4 points is a minimum qualification and should not be considered perfection. Each operator should strive to perfect his technique to obtain results equivalent to those of the mechanical shaker method.

8.5 Operators should be required to perform qualification test whenever their results tend to vary appreciably from those obtained using the mechanical shaker method. Qualification tests should be made at regular intervals to assure a reasonable degree of accuracy and standardization of test results.

METHODS OF SAMPLING AND TESTING
MT 214-04
RECOMMENDED PRACTICE FOR THE CLASSIFICATION OF SOILS AND SOIL-AGGREGATE MIXTURES FOR HIGHWAY CONSTRUCTION PURPOSES
(Modified AASHTO M 145)

1 Scope:

1.1 This recommended practice describes a procedure for classifying soils into seven groups based on laboratory determination of particle-size distribution, liquid limit and plasticity index. Evaluation of soils within each group is made by means of a "group index," which is a value calculated from an empirical formula. The group classification, including group index, should be useful in determining the relative quality of the soil material for use in earthwork structures, particularly embankments, sub-grades, sub-bases, and bases. However, for the detailed design of important structures, additional data concerning strength or performance characteristics of the soil under field conditions will usually be required.

2 Referenced Documents:

2.1 ***AASHTO:***

T 11 Materials Finer Than 75-µm (No. 200) Sieve in Aggregates by Washing
T 27 Sieve Analysis of Fine and Coarse Aggregates
T-88 Particle Size Analysis of Soils
M 145 Classification of Soil and Soil-Aggregate Mixtures for Highway Construction Purposes
T-146 Wet Preparation of Disturbed Soil Samples for Test

MT Manual:

MT-200 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test
MT-202 Sieve Analysis of Fine and Coarse Aggregates
MT-208 Determining the Plastic Limit and Plasticity Index of Soils
MT-208 Determining the Liquid Limit of Soils

ASTM:

D 1140 Amount of Material in Soils Finer Than the No. 200 (75 µm) Sieve

Note 1 - Either AASHTO T 88, or T 11 and T 27, or ASTM D 1140 will be used to determine the particle size distribution of soils or soil-aggregate mixtures as a basis for classification.

3 Classification:

3.1 The classification is made by using the test limits and group index values shown in Table 1. If a more detailed classification is desired, a further subdivision of the groups shown in Table 1 may be made. An example of the classification with such subgroups as shown in Table 1 may be made. An example of the classification with such subgroups is shown in Table 2. The liquid limit and plasticity index ranges for the A-4, A-5, A-6, and A-7 soil groups are shown graphically in Figure 2.

3.2 *Classification Procedure* - With required test data available, proceed from left to right in Table 1 or Table 2 and the correct group will be found by process of elimination. The first group from the left into which the test data will fit is the correct classification. All limiting test values are shown as whole numbers. If fractional numbers appear on test reports, convert to nearest whole number for purposes of classification. Group index values should always be shown in parentheses after group symbol as: A-26(3), A-4(5), A-6(12), A-7-5(17), etc.

TABLE 1 Classification of Soils and Soil-Aggregate Mixtures

General Classification	Granular Materials (35% or Less Passing 0.075 mm)			Silt-Clay Materials (More than 35% Passing 0.075 mm)			
Group Classification	A-1	A-3[a]	A-2	A-4	A-5	A-6	A-7
Sieve analysis, percent passing:							
2.00 mm (No. 10)	—	—	—	—	—	—	—
0.425 mm (No. 40)	50 max.	51 min.	—	—	—	—	—
0.075 mm (No. 200)	25 max.	10 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing 0.425 mm (No. 40)							
Liquid limit	—	—		40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.	N.P.	[b]	10 max.	10 max.	11 min.	11 min.
General rating as subgrade	Excellent to good			Fair to poor			

[a] The placing of A-3 before A-2 is necessary in the "left to right elimination process" and does not indicate superiority of A-3 over A-2.
[b] See Table 2 for values.

TABLE 2 Classification of Soils and Soil-Aggregate Mixtures

General Classification	Granular Materials (35% or Less Passing 0.075 mm)							Silt-Clay Materials (More than 35% Passing 0.075 mm)			
	A-1			A-2							A-7
Group Classification	A-1-a	A-1-b	A-3	A-2-4	A-2-5	A-2-6	A-2-7	A-4	A-5	A-6	A-7-5, A-7-6
Sieve analysis, percent passing:											
2.00 mm (No. 10)	50 max.	—	—	—	—	—	—	—	—	—	—
0.425 mm (No. 40)	30 max.	50 max.	51 min.	—	—	—	—	—	—	—	—
0.075 mm (No. 200)	15 max.	25 max.	10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min	36 min	36 min.
Characteristics of fraction passing 0.425 mm (No. 40)											
Liquid limit	—		—	40 max.	41 min.	40 max	41 min	40 max.	41 min	40 max	41 min.
Plasticity index	6 max.		N.P.	10 max	10 max.	11 min.	11 min	10 max	10 max.	11 min	11 min.*
Usual types of significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
General Ratings as Subgrade	Excellent to Good							Fair to poor			

* Plasticity index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity index of A-7-6 subgroup is greater than LL minus 30 (see Figure 2).

4 Definitions of Gravel, Sand, and Silt-Clay:

4.1 The terms "gravel," "coarse sand," and "silt-clay," as determinable from the minimum test data required in this classification arrangement, and as used in subsequent word descriptions, are defined as follows:

4.1.1 *Gravel* - Material passing sieve with 75 mm (3-in.) square openings and retained on the 2.00 mm (No. 10) sieve.

4.1.2 *Coarse Sand* - Material passing the 2.00 mm (No. 10) sieve and retained on the 0.425 mm (No. 40) sieve.

4.1.3 *Fine Sand* - Material passing the 0.425 mm (No. 40) sieve and retained on the 0.075 mm (No. 200) sieve.

4.1.4 *Silt Clay (combined silt and clay)* - Material passing the 0.075 mm (No. 200) sieve.

4.1.5 *Boulders and Cobbles* [retained on 75 mm (3 in.) sieve] should be excluded from the portion of the sample to which the classification is applied, but the percentage of such material, if any, in the sample should be recorded.

Note - *The revised specification is identified as Interim Specification M 149.91 I.*

4.1.6 The term "silty" is applied to fine material having plasticity index of 10 or less and the term "clayey" is applied to fine material having plasticity index of 11 or greater.

5 Description of Classification Groups:

5.1 *Granular Materials* - Containing 35 percent or less passing 0.075 mm (No. 200) sieve, Note 2.

5.1.1 *Group A-1* - The typical material of this group is a well-graded mixture of stone fragments or gravel, coarse sand, fine sand and a nonplastic or feebly plastic soil binder. However, this group includes also stone fragments, gravel, coarse sand, volcanic cinders, etc. without soil binder.

5.1.1.1 *Subgroup A-1-a* includes those materials consisting predominantly of stone fragments or gravel, either with or without a well-graded binder of fine material.

5.1.1.2 *Subgroup A-1-b* includes those materials consisting predominantly of coarse sand either with or without a well-graded soil binder.

5.1.2 *Group A-3* - The typical material of this group is fine beach sand or fine desert blow sand without silty or clay fines or with a very small amount of nonplastic silt. The group includes also stream-deposited mixtures of poorly-graded fine sand and limited amounts of coarse sand and gravel.

5.1.3 *Group A-2* - This group includes a wide variety of "granular" materials which are border-line between the materials falling in Groups A-1 and A-3 and silt-clay materials of Groups A-4, A-5, A-6, and A-7. It includes all materials containing 35 percent or less passing the 0.075 mm (No. 200) sieve which cannot be classified as A-1 or A-3, due to fines content or plasticity, or both, in excess of the limitations for those groups.

5.1.3.1 Subgroups A-2-4 and A-2-5 include various granular materials containing 35 percent or less passing the 0.075 mm (No. 200) sieve and with a minus 0.425 mm (No. 40) portion having the characteristics of the A-4 and A-5 groups. These groups include such materials as gravel and coarse sand with silt contents or plasticity indexes in excess of the limitations of Group A-1, and fine sand with nonplastic silt content in excess of the limitations of Group A-3.

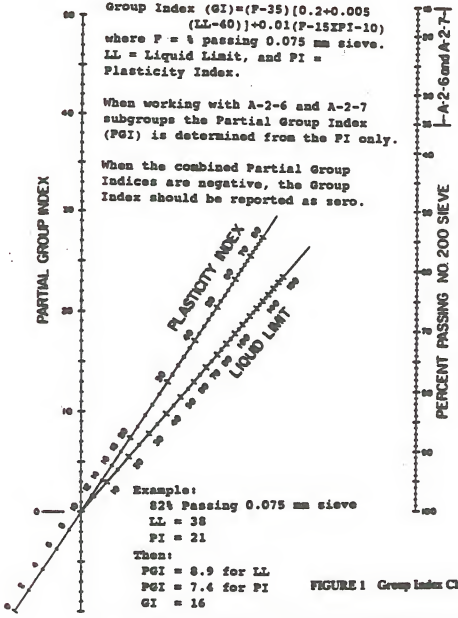
5.1.3.2 Subgroups A-2-6 and A-2-7 include materials similar to those described under Subgroups A-2-4 and A-2-5, except that the fine portion contains plastic clay having the characteristics of the A-6 or A-7 group.

MT-214

Group Index (GI)=(F-35)[0.2+0.005 (LL-40)]+0.01(F-15XPI-10)
where F = % passing 0.075 mm sieve.
LL = Liquid Limit, and PI = Plasticity Index.

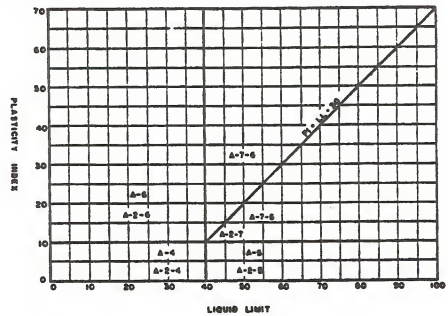
When working with A-2-6 and A-2-7 subgroups the Partial Group Index (PGI) is determined from the PI only.

When the combined Partial Group Indices are negative, the Group Index should be reported as zero.



Example:
82% Passing 0.075 mm sieve
LL = 38
PI = 21
Then:
PGI = 8.9 for LL
PGI = 7.4 for PI
GI = 16

FIGURE 1 Group Index Chart



NOTE—A-2 soils contain less than 35 % finer than 200 sieve.

5 Description of Classification Groups: (continued)

Note 2 - Classification of materials in the various groups applies only to the fraction passing the 75 mm (3-in.) sieve. Therefore, any specifications regarding the use of A-1, A-2, or A-3 materials in construction should state whether boulders retained on the 75 mm (3-in.) sieve are permitted.

5.2 *Silt-Clay Materials* - Containing more than 35 percent passing the 0.075 mm (No. 200) sieve.

5.2.1 *Group A-4* - The typical material of this group is a nonplastic or moderately plastic silty soil usually having the 75 percent or more passing the 0.075 mm (No. 200) sieve. The group includes also mixtures of fine silty soil and up to 64 percent of sand and gravel retained on 0.075 mm (No. 200) sieve.

5.2.2 *Group A-5* - The typical material of this group is similar to that described under Group A-4, except that it is usually of diatomaceous or micaeous character and may be highly elastic as indicated by the high liquid limit.

5.2.3 *Group A-6* - The typical material of this group is a plastic clay soil usually having 75 percent or more passing the 0.075 mm (No. 200) sieve. The group includes also mixtures of fine clayey soil and up to 64 percent of sand and gravel retained on the 0.075 mm (No. 200) sieve. Materials of this group usually have high volume change between wet and dry states.

5.2.4 *Group A-7* - The typical material of this group is similar to that described under Group A-6, except that it has the high liquid limits characteristic of the A-5 group and may be elastic as well as subject to high volume change.

5.2.4.1 Subgroup A-7-5 includes those materials with moderate plasticity indexes in relation to liquid limit and which may be highly elastic as well as subject to considerable volume change.

5.2.4.2 Subgroup A-7-6 includes those materials with high plasticity indexes in relation to liquid limit and which are subject to extremely high volume change.

Note 3 - Highly organic soils (peat or much) may be classified in an A-8 group. Classification of these materials is based on visual inspection, and is not dependent on percentage passing the 0.075 mm (No. 200) sieve, liquid limit or plasticity index. The material is composed primarily of partially decayed organic matter, generally has a fibrous texture, dark brown or black color and odor of decay. These organic materials are unsuitable for use in embankments and sub-grades. They are highly compressible and have low strength.

6 Group Index:

6.1 The group index is calculated from the following formula:

Group index = (F-35)[0.2 + 0.005(LL-40)] + 0.01(F-15)(PI-10),

in which,

F = percentage passing 0.075 mm (No. 200) sieve, expressed as a whole number. This percentage is based only on the material passing the 75 mm (3-in.) sieve.

LL = liquid limit

PI = plasticity index

6.1.1 When the calculated group index is negative, the group index shall be reported as zero (0).

6.1.2 The group index should be reported to the nearest whole number.

6.2 Figure 1 may be used in estimating the group index, by determining the partial group index due to liquid limit and that due to plasticity index, then obtaining the total of the two partial group indexes.

6 **Group Index:** (continued)

6.3 When calculating the group index of A-2-6 and A-2-7 subgroups, only the PI portion of the formula (or of Figure 1) shall be used.

6.4 The following are examples of calculations of the group index:

6.4.1 Assume that an A-6 material has 55 percent passing the 0.075 mm (No. 200) sieve, liquid limit of 40, and plasticity index of 25. Then,

Group = (55-35)[0.2 + 0.005(40-40)] + 0.01(55-15) (25-10) = 4.0 + 6.0 = 10

6.4.2 Assume that an A-7 material has 80 percent passing the 0.075 mm (No. 200) sieve, liquid limit of 90, and plasticity index of 50. Then,

Group index = (80-35)[0.2 + 0.005(90-40)] + 0.01 (80-15)(50-10) = 20.3 + 26.0, or 46.3

6.4.3 Assume that an A-4 material has 60 percent passing the 0.075 mm (No. 200) sieve, liquid limit of 25, and plasticity index of 1. Then,

Group index = (60-35)[0.2 + 0.005(25-40)] + 0.01 (60-15)(1-10) = 25 X (0.2 - 0.075) + 0.01(45)(-9)
= 3.1 - 4.1 = 4.1 = - 1.0
Report as 0.

6.4.4 Assume that an A-2-7 material has 30 percent passing the 0.075 mm (No. 200) sieve, liquid limit of 50, and plasticity index of 30. Then,

Group index = 0.01(30-15)(30-10) = 3.0 or 3 (Note that only the PI portion of formula was used.)

7 **Basis for Group Index Formula:**

7.1 The empirical group index formula devised for approximately within-group evaluation of the "clayey granular materials" and the "silt-clay materials" is based on the following assumptions:

7.1.1 Materials falling within Groups A-1-a, A-1-b, A-2-4, A-2-5, and A-3 are satisfactory as subgrade when properly drained and compacted under moderate thickness pavement (base and/or surface course) of a type suitable for the traffic to be carried, or can be made satisfactory by additions of small amounts of natural or artificial binders.

7.1.2 Materials falling within the "clayey granular" Groups A-2-6 and A-2-7 and the "silt-clay" Groups A-4, A-5, A-6, and A-7 will range in quality as sub-grade from the approximate equivalent of the good A-2-4 and A-2-5 sub-grades to fair and poor sub-grades requiring a layer of sub-base material or an increased thickness of base course over that required under 7.1.1 in order to furnish adequate support for traffic loads.

7.1.3 The assumed critical minimum percentage passing the 0.075 mm (No. 200) sieve is 35 neglecting plasticity, and 15 as affected by plasticity indexes greater than 10.

7.1.4 Liquid limits of 40 and above are assumed to be critical.

7.1.5 Plasticity indexes of 10 and above are assumed to be critical.

7.1.6 For soils that are non-plastic and when the liquid limit cannot be determined, the group index shall be considered zero (0).

7.2 There is no upper limit of group index value obtained by use of the formula. The adopted critical values of percentage passing the 0.075 mm (No. 200) sieve, liquid limit and plasticity index, are based on an evaluation of sub-grade, sub-base and base course materials by several highway organizations that use the tests involved in this classification system.

7 **Basis for Group Index Formula:** (continued)

7.3 Under average conditions of good drainage and thorough compaction, the supporting value of a material as sub-grade may be assumed as an inverse ratio to its group index, that is, a group index of 0 indicates a "good" sub-grade material and a group index of 20 or greater indicates a "very poor" sub-grade material.

METHODS OF SAMPLING AND TESTING
MT 215-04
DETERMINATION OF MOISTURE IN SOILS BY MEANS OF A CALCIUM CARBIDE GAS PRESSURE MOISTURE TESTER
(Modified AASHTO T 217)

1 Scope:

1.1 This method of test is intended to determine the moisture content of soils by means of a calcium carbide gas pressure moisture tester.

1.2 The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with the rounding-off method of AASHTO R 11, Recommended Practice for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values.

Note 1 - This method shall not be used on granular materials having particles large enough to affect the accuracy of the test -- in general any appreciable amount retained on a 4.75 mm sieve. The super 200 D tester is intended to be used to test aggregate.

2 Referenced Documents:

2.1 ***AASHTO:***
T 217 Determination of Moisture in Soils by Means of a Carbide Gas Pressure Moisture Tester

3 Apparatus:

3.1 Calcium carbide pressure moisture tester.

3.2 Taped scale.

3.3 Two 1¼ inch (31.75) mm) steel balls.

3.4 Cleaning brush and cloth.

3.5 Scoop for measuring calcium carbide reagent.

4 Material:

4.1 Calcium carbide reagent.

Note 2 - The calcium carbide must be finely pulverized and should be of a grade capable of producing acetylene gas in the amount of at least 2.25 cu. ft./lb. (0.14 m^3/kg) of carbide.

Note 3 - The "shelf life" of the calcium carbide reagent is limited, so it should be used according to the manufacturer's recommendations.

5 Procedure:

5.1 When using the 20 g or 26 g tester, place three scoops (approximately 24 g) of calcium carbide in the body of the moisture tester. When using the super 200 D tester to test aggregate, place six scoops (approximately 48 g) of calcium carbide in the body of the moisture tester.

Note 4 -Care must be exercised to prevent the calcium carbide from coming into direct contact with water.

5 Procedure: (continued)

5.2 Weigh a sample of the exact weight specified by the manufacturer of the instrument in the balance provided, and place the sample in the cap of the tester. When using the 20 g or 26 g size tester, place two 1¼" (31.75 mm) steel balls in the body of the tester with the calcium carbide.

Note 5 - If the moisture content of the sample exceeds the limit of the pressure gage (12 percent moisture for aggregate tester or 20 percent moisture for soil tester), a one-half size sample must be used and the dial reading must be multiplied by 2. This proportional method is not directly applicable to the dry weight percent scale on the super 200 D tester.

5.3 With the pressure vessel in an approximately horizontal position, insert the cap in the pressure vessel and seal the unit by tightening the clamp, taking care that no carbide comes in contact with the soil until a complete seal is achieved.

4.4 Raise the moisture tester to a vertical position so that the soil in the cap will fall into the pressure vessel.

5.5 Shake the instrument vigorously so that all lumps will be broken up to permit the calcium carbide to react with all available free moisture. When steel balls are being used in the tester and when using the large tester to test aggregate, the instrument should be shaken with rotating motion so the steel balls or aggregate will not damage the instrument or cause soil particles to become embedded in the orifice leading to the pressure diaphragm.

Note 6 - Shaking should continue for at least 1 min. with granular soils and up to 3 min. for other soils so as to permit complete reaction between the calcium carbide and the free moisture. Time should be permitted to allow dissipation of the heat generated by the chemical reaction.

5.6 When the needle stops moving, read the dial while holding the instrument in a horizontal position at eye level.

5.7 Record the sample mass and the dial reading.

5.8 With the cap of the instrument pointed away from the operator, slowly release the gas pressure. Empty the pressure vessel and examine the material for lumps. If the sample is not completely pulverized, the test should be repeated using a new sample. Clean the cap thoroughly of all carbide and soil before running another test.

Note 7 - When removing the cap, care should be taken to point the instrument away from the operator to avoid breathing the fumes, and away from any potential source of ignition for the acetylene gas.

5.9 The dial reading is the percent of moisture by wet mass and must be converted to dry mass. With the super 200 D tester, the dial reading is the percent of moisture by dry weight, and no further calculation is required.

6 Calculation:

6.1 The percentage of moisture by dry mass of the soil may be determined from the conversion curve. (Figure 1).

Note 8 - A conversion curve similar to Figure 1 is normally supplied with the moisture tester. However, each moisture tester should be checked for accuracy of its gage, or for the accuracy of the conversion curve. Accuracy of the tester gage may be checked by using a calibration kit (obtainable from the tester manufacturer), equipped with standard gage; in case of discrepancy, the gage on the tester should be adjusted to conform with the standard gage. For checking the accuracy of the conversion curve, a calibration should be made for meter readings using locally

6 Calculation: (continued)

prepared soils at known moisture contents. Also additional testing may be necessary to extend the conversion curve (Figure 1) beyond 44 percent moisture content.

Note 9 - It may be more convenient for field use of the apparatus to prepare a table of moisture tester readings versus oven-dry moisture content for the moisture tester.

6.2 Determine the percentage of moisture to the nearest whole percent.

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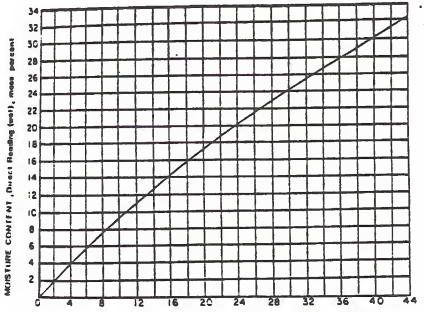


FIGURE 1 Conversion Curve for Moisture Tester Reading

METHODS OF SAMPLING AND TESTING
MT 216-04
METHOD OF SAMPLING AND TESTING CEMENT TREATED BASE
(Montana Test Method)

1 Scope:

1.1 This method covers the sampling and testing of: (1) the proposed mineral aggregate to establish a preliminary mix design, (2) the prepared mineral aggregate from the stockpiled material to establish the final mix design, and (3) acceptance samples of the cement treated base aggregate and mixture during construction.

2 Referenced Documents:

2.1 ***MT Manual:***
MT-201 Sampling Roadway Materials
MT-211 Moisture Density Relations of Soil-Cement Mixtures
MT-212 Determination of Moisture and Density of In-Place Materials

3 Mineral Aggregate:

3.1 The sampling required for the mineral aggregate will be as follows:

3.2 *Proposed Mineral Aggregate* – Mineral aggregate from the proposed source must be submitted to the Materials Bureau as part of the pre-construction proposed surfacing package. See MT-201, Sampling Roadway Materials.

3.3 *Prepared Mineral Aggregate* - A 300 lb. (136 Kg) sample of the mineral aggregate shall be submitted to the Materials Bureau for the proposed mix design as needed. The procedure is as follows:

3.3.1 The stockpile shall be sampled according to MT-201, paragraph 10 - (Stockpile Samples) and then be submitted to the Materials Bureau for the mix design after sufficient quantity has been accumulated to insure a satisfactory average stockpile gradation.

3.3.2 Gradation test results of the stockpile and the contractor's Job Mix Target shall accompany the sample.

3.3.3 The stockpile average shall be shown on the laboratory work sheet that accompanies the sample.

3.3.4 When the sample of mineral aggregate, prepared in accordance with 3.3.1 through 3.3.2, has been received in the Materials Bureau, it will be tested to determine the mix design as follows:

3.3.4.1 A moisture-density determination will be made, using the median cement content that was determined in the preliminary investigation.

3.3.4.2 Using the optimum moisture and maximum density as determined in AASHTO T134, a 7-day and a 28-day compressive specimen and a freeze-thaw and wet-dry specimen will be molded for each of three cement contents (one cement content will be at the median, one at 1% less than median, and one at 1% more than median).

3.4 At the conclusion of the testing described in 3.3.4, a mix design will be established consisting of:

3.4.1 The optimum moisture content,

3 Mineral Aggregate: (continued)

3.4.2 The maximum density,

3.4.3 The recommended cement content, (% of cement by wt. of dry aggregate)

3.4.4 Minimum 7-day compressive strength requirement.

4 Acceptance:

4.1 After a satisfactory mix design has been established and construction has begun, the following sampling should be accomplished:

4.1.1 Cement Content Determinations. After the contractor has succeeded in producing a uniform mixture of the cement treated base, a sample will be tested for cement content. It is necessary to have the following samples to determine cement content:

4.1.1.1 A sample of cement used in the mixture.

4.1.1.2 A sample of the mineral aggregate before the addition of the cement. This sample shall be marked "Mineral Aggregate for Cement Content."

4.1.1.3 One of the 7-day compressive specimens. After the compressive strength has been determined the specimen will be pulverized in the Materials Bureau and used as the sample of the mixture for the cement content determination.

4.1.2 *In-Place Densities* - In-place densities will be determined in accordance with MT-212. A corrected moisture curve must be established by correcting the nuclear moisture reading to oven-dry moisture contents.

4.1.3 *Field-Made Compression Specimens* - A minimum of one set of specimens per two-lane mile per lift shall be molded in accordance with paragraph 4 described below. It is desirable that these specimens represent the material placed at the locations of the in-place densities in order that moisture-density comparisons can be made. One specimen will be tested as a 7-day compression specimen and the other as a 28-day compression specimen. The Materials Bureau will supply shipping boxes and blank forms to accompany samples. A copy of the form to accompany specimens will be placed in the plastic envelope in the shipping box and a copy mailed to the Materials Bureau.

4.1.3.1 Additionally, after the plant is producing satisfactorily, wet-dry and freeze-thaw cylinders are required. One set (2 cylinders per test) shall accompany a set of compressive strength specimens.

4.1.4 *Acceptance Samples of Mineral Aggregate* - Acceptance samples for gradation analysis shall be taken in accordance with contract specifications. See MT-601 - "Aggregate, Cement Treated Base, When Used."

5 Molding Specimens in the Field:

5.1 Specimens shall be molded in the field and shipped to the Materials Bureau for compressive testing as follows:

5.1.1 The material to be molded shall be the mixture of CTB placed on the roadway. It must be transported to the place of molding as quickly as possible in order to minimize hydration. (Excessive hydration can reduce the lubrication properties and result in less than maximum density and therefore lower strengths.)

5 Molding Specimens in the Field: (continued)

5.1.2 The apparatus shall be the same as described in MT-211. (Moisture-Density Relations of Soil-Cement Mixtures).

5.1.3 Form a specimen by immediately compacting the mixture in the mold, (with the collar attached) and later trimming the specimen in accordance with Section 7.2 in MT-211, and in addition:

5.1.3.1 Spade along the inside of the mold with a spatula as the mixture for each layer is placed in the mold and before compaction, to obtain uniform distribution of the material retained on the 4 Mesh (4.75 mm) sieve.

5.1.3.2 During compaction, obtain a representative sample of the mixture, weighing not less than 500 grams. Weigh the sample immediately and dry in an oven at 230 " 9°F (110 " 5°C) at least 12 hours or to constant mass to determine the moisture content as a check against design moisture content.

5.1.3.3 Weigh the compacted specimen to check against design density and permit to cure for 24 hours. (Note 1)

Note 1 - During the initial curing period, the specimen must be kept damp and maintained as nearly as possible at a temperature of 73.4 " 3°F (23 " 1.7°C).

5.1.4 In the same manner form a second specimen as rapidly as possible. One specimen will be identified as a 7-day compression specimen, the other a 28-day compression specimen. Also wet-dry and freeze-thaw specimens may be made as indicated in 4.1.3.1. (Note 2).

Note 2 - A satisfactory method of identifying the specimens for the 7-days or 28-days, of curing in the moist room, is to wrap a piece of masking tape around the specimen. Indicate on the masking tape the making date, stationing lane, type of test, etc. Allow sufficient space for the Materials Bureau to show the laboratory number and the breaking date.

5.1.5 At the conclusion of the initial curing period, place the compressive specimens and the wet-dry and freeze-thaw specimens in the shipping box, packed in damp sawdust, and transport to the Materials Bureau as soon as possible in order that final curing can be accomplished in the approved curing room.

METHODS OF SAMPLING AND TESTING
MT 217-04
METHOD OF TEST FOR DETERMINING PERCENTAGE OF MECHANICALLY FRACTURED PARTICLES

1 Scope:

1.1 This test method covers the determination of the percentage, by mass or by count, of a coarse aggregate sample that consists of fractured particles meeting specified requirements.

1.2 The values stated in SI units are to be regarded as the standard. The values in parentheses are provided for information only.

2 Referenced Documents:

2.1 ***ASTM:***
D 5821 Standard Test Method for Determining the Percentage of Fractured Particles in Coarse Aggregate

WAQTC: TM-1 Determining the Percentage of Fractured Particles in Coarse Aggregate

MT Manual:
MT-201 Sampling Roadway Materials
MT-202 Sieve Analysis for Coarse and Fine Aggregate
MT-405 Wire Cloth Sieves for Testing Purposes
MT-417 Procedure for Reducing Field Samples to Testing Size

3 Terminology:

3.1 Definitions:

3.1.1 *Fractured face, n* – an angular, rough, or broken surface of an aggregate particle created by crushing, by other artificial means, or by nature.

3.1.2 *Discussion* – for this standard, a face will be considered a "fractured face" only if it has a projected area at least as large as one quarter of the maximum projected area (maximum cross-sectional area) of the particle and the face has sharp and well-defined edges; this excludes small nicks

3.1.3 *Fractured particle, n* – a particle of aggregate having at least the minimum number of fractured faced specified (usually one or two).

3.1.4 *Nominal Maximum Size* – One sieve size larger than the first sieve to retain more than 10 percent.

4 Significance and Use:

4.1 Some specifications contain requirements relating to percentage of fractured particles in coarse aggregates. One purpose of such requirements is to maximize shear strength by increasing inter-particle friction in either bound or unbound aggregate mixtures. Another purpose is to provide stability for surface treatment aggregates and to provide increased friction and texture for aggregates used in pavement surface courses. This test method provides a standard procedure for determining the acceptability of coarse aggregate with respect to such requirements.

4 Significance and Use: (continued)

4.2 Specifications differ as to the number of fractured faces required on a fractured particle, and they also differ as to whether percentage by mass or percentage by particle count shall be used. If the specification does not specify, use the criterion of at least one fractured face and calculate percentage by mass.

5 Apparatus:

5.1 *Balance* - A balance or scale accurate and readable to within 0.1% of the test sample mass at any point within the range of use.

5.2 *Sieves* - Sieves shall be of the woven wire type with square openings and shall conform to MT-405.

5.3 *Splitter* – A sample splitter suitable for dividing field samples into test portion sizes according to MT-417.

5.4 *Spatula* - A spatula or similar tool to aid in sorting aggregate particles.

6 Sampling:

6.1 Sample and reduce the aggregate in accordance with MT-201 and MT-417.

7 Sample Preparation:

7.1 Dry the sample sufficiently to obtain a clean separation of fine and coarse material in the sieving operation. Sieve the sample in accordance with MT-202 over the 4.75 mm (No. 4) sieve, or other specified sieve for retaining material for this test, and reduce the portion retained on the sieve using a splitter in accordance with MT-417 to the appropriate size for test. This test size should be slightly larger than shown in Table 1 to account for loss of fines through washing, if necessary.

Note - When individual sieve fracture determination is required, such as in the Special Provisions for a Grade "S" mix design, the test sample size will be determined using Table 2.

7.2 For aggregate with a nominal maximum size of 19.0 mm (3/4 in.) or larger, where the fracture particle content is to be determined for material retained on the 4.75 mm (No. 4) or smaller sieve, the test sample may be separated on the 9.5 mm (3/8 in.) sieve. The portion passing the 9.5 mm (3/8 in.) sieve may then be further reduced, in accordance with MT-417, to a minimum of 200 g (0.5 lbs.). This will reduce the number of particles to be separated during the procedure. In this case, percent fractured particles is determined on each portion; and a weighted average of fractured particles is calculated based on the mass of each of the portions to reflect the total percentage of fractured particles in the entire sample.

Combined Fracture Determination
TABLE 1

Nominal Maximum Size Square Openings, mm (in.)	Minimum Test Sample Mass, grams (Approx. lb.)
4.75 (No.4)	200 (0.4)
9.5 (3/8)	400 (0.9)
12.5 (1/2)	700 (1.5)
19.0 (3/4)	1,000 (2.5)
25.0 (1)	1,500 (3.5)
37.5 (11/2)	2,500 (6)
50.0 (2)	4,000 (8.8)
63.0 (21/2)	7,500 (16.5)
75.0 (3)	10,000 (27)
90.0 (31/2)	15,000 (33)

Note - Nominal maximum size is one sieve size larger than the first sieve to retain more than 10 percent of the material.

Individual Sieve Fracture Determination
TABLE 2

Nominal Maximum Size Square Openings, mm (in.)	Minimum Test Sample Mass, grams (Approx. lb.)
2.00 (No.10)	25 (0.1)
2.36 (No.8)	25 (0.1)
4.75 (No.4)	100 (0.4)
6.3 (¼)	100 (0.2)
9.5 (3/8)	200 (0.5)
12.5 (2)	300 (0.7)
16.0 (5/8)	500 (1)
19.0 (3/4)	700 (1.5)
25.0 (1)	1,000 (2.2)
31.5 (11/4)	1,500 (3.5)

8 Procedure:

8.1 Wash the sample, when necessary, over the sieve designated for determination of fractured particles to remove any remaining fine material, and dry to a constant mass in accordance with MT-202. Determine the mass of the test sample, and any subsequent determination of mass, to the nearest 0.1% of the original dry sample mass.

8.2 Spread the dried test sample on a clean flat surface large enough to permit careful inspection of each particle. To verify that a particle meets the criteria, hold the aggregate particle so that the face is viewed directly. If the face constitutes at least one quarter of the maximum cross sectional area of the rock particle, consider it a fractured face.

8.3 Using the spatula or similar tool, separate the test sample into three categories: (1) fractured particle based on whether the particle has the required number of fractured faces, (2) particles not meeting the specified criteria, and (3) questionable or borderline particles. If the required number of fractured faces is not given in the applicable specifications, the determination will be made on the basis of a minimum of one fractured face.

8 Procedure: (continued)

8.4 To aid in making the fracture determination, separate the sample into three categories. Determine the mass or count of particle in the fractured particle category, the mass or count of the questionable particles, and the mass or count of the particle not meeting the specified fracture criteria. Use mass to calculate percent fractured particles unless percentage by particle count is specified.

8.5 If more than one number of fractured faces is specified (for example, 90% with one or more fractured faces and 60% with two or more fractured faces), repeat the procedure on the same sample for each requirement.

8.6 If on any of the determinations, more than 15% of the total is placed in the questionable pile, repeat the determination until no more than 15% is present in that category. Use percent based on mass for this determination unless percent by particle count is specified. Also, if the sample has been divided into two test portions, the 15% criteria shall apply to each.

9 Report:

9.1 Report the mass percentage of fractured faces to the nearest 1% in accordance with the following:

$$P = [F + Q/2)/(F + Q + N)] \times 100$$

P = percentage of particle with the specified number of fractured faces,

F = mass or, count of fractured particles with at least the specified number of fractured faces,

Q = mass of count of particles in the questionable or borderline category, and

N = mass or count of particles in the uncrushed category not meeting the fractured particle criteria.

Example:

F = 632.6 g, Q = 97.6 g, N = 352.3 g

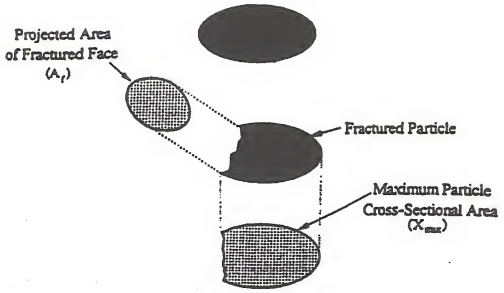
$$P = [(632.6 \text{ g} + 97.6 \text{ g}/2)/(632.6 \text{ g} + 97.6 \text{ g} + 352.3 \text{ g})] \times 100 = 62.9\%$$

9.2 Report the specified fracture criteria against which the sample was evaluated.

9.3 Report the total mass in grams of the coarse aggregate sample tested.

9.4 Report the sieve on which the test sample was retained at the start of the test.

9.5.1 Report whether the percentage of fractured particles was determined by mass or by particle count.



A face will be considered a "Fractured Face" only if it has : $A_f \geq 0.25\ X_{max}$

FIG. 1 Schematic of a Fractured Particle with One Fractured Face

Fig. 1 reprinted with the permission of the American Society for Testing Materials

METHODS OF SAMPLING AND TESTING
MT 218-04
METHOD OF TEST FOR
DETERMINING RELATIVE COMPACTION AND PERCENT MOISTURE
(Montana Test Method)

1 Scope:

1.1 This procedure is intended as a guide for comparing in-place moisture and density to optimum moisture and maximum density, respectively, in order to determine compliance with standard specifications and contract special provisions.

2 Referenced Documents:

2.1 ***MT Manual:***
MT-210 Moisture-Density Relations of Soils Using a 5.5 lb. Rammer
MT-212 Determination of Moisture and Density of In-Place Materials
MT-230 Moisture-Density Relations of Soils Using a 10 lb. Rammer

3 In-Place Moisture and Density:

3.1 The in-place moisture and density shall be determined in accordance with MT-212.

4 Optimum Moisture and Maximum Density:

4.1 The optimum moisture and maximum density shall be determined in accordance with MT-210 or MT-230, Method A, B, C, or D, whichever is applicable, using the following criteria as a guide.

4.1.1 When the material under test is a soil or aggregate consisting of entirely minus 4 mesh (4.75 mm), Method A or B will be used.

4.1.2 When the material under test is a soil or aggregate with a maximum size of 3/4 inch (19.0) mm), Method C or D will be used.

4.1.3 When the material under test is a soil or aggregate with a maximum size of 2 inches (50 mm), Method D will be used.

4.1.4 When the material under test is a soil or aggregate with a maximum size of 4 inches (100 mm) and no more than 50% of the material under test is retained on the 4 mesh (4.75 mm), Method D will be used.

4.1.5 When the material under test is a soil or aggregate with a maximum size larger than 2 inches (50 mm) and more than 50% of the material under test is retained on the 4 mesh (4.75 mm), the material will not be required to meet 95% density within 2% optimum moisture but:

4.1.5.1 A screen analysis must be provided on representative samples from each lift of the embankment area to prove that more than 50% of the material is retained on the 4 mesh (4.75 mm) sieve.

4.1.5.2 Nuclear M/D readings must be taken on each lift in the embankment area to demonstrate that uniform relative density has been achieved.

4.1.5.3 Notes must be made on the Summary of Compaction Data (Form 1006) showing the results obtained in paragraphs 4.1.5.1 and 4.1.5.2.

5 Calculation:

5.1 Determine the relative compaction by dividing the in-place density (pounds per cubic foot) by the maximum density (pounds per cubic foot) and multiplying by 100.

5.2 A direct comparison of the in-place moisture and the optimum moisture will determine compliance with specifications.

6 Family of Curves:

6.1 A "family of curves" is a term applied to a number of moisture-density curves which are plotted on one cross-section sheet, using the same ordinates and abscissas as dry weights pounds per cubic foot and moisture contents, respectively. The family of curves is plotted, initially, from values obtained by the sampling and testing of the various soil types during the Preconstruction Soils Survey and every effort must be made to sample and identify all of the various soil types that will be encountered on the project. Each new soil type, or mixture of soils, encountered on the project during construction, will be represented by a moisture-density curve, which is added to the "family".

Note 1 – New curves drawn through plotted one-point determinations shall not become a permanent part of the family of curves until verified by a full moisture-density relationship.

7 One Point Proctors:

7.1 A "one point Proctor" is an abbreviated standard Proctor compaction test and is used in conjunction with the family of curves. Rather than determining the moisture and density points for an entire curve, a single point is determined for the purpose of selecting the curve, which represents the soil being compacted, from the family of curves.

7.1.1 One-point Proctors shall be run whenever there is any doubt that the soil being compacted is from a location on the project, which is represented, by one of the curves in the family of curves.

7.1.2 Frequently soils may be mixed by heavy equipment excavating and hauling to the embankment site and a one-point Proctor may not fit any of the established curves. In these cases a new curve will have to be prepared from the mixture and added to the family of curves.

7.1.3 It is necessary to run the one-point Proctor as close to optimum moisture as possible. The point should be within plus or minus three percent of optimum on most curves and within plus or minus two percent of optimum on sharp breaking curves. If the point is established on either side of optimum and some distance from the peak of the curve, it may very well fit more than one curve in the family of curves, or none at all and it will be impossible to select the proper curve.

7.1.4 The moisture and density results obtained by the one-point Proctor are plotted on the family of curves and, when obtained near optimum, will fall near one of the curves in the family of curves, provided that particular type of soil or mixture of soils has been tested for optimum moisture and maximum density. The peak of the curve selected shall be considered the optimum moisture and maximum density of the material represented by the one-point Proctor.

Note 2 – If the one-point plotted within or on the family of curves does not fall in the 80 to 100 percent of optimum moisture range, compact another specimen, using the same material, at an adjusted moisture content that will place the one-point within this range.

8 Numbering Check Samples:
When a check sample is taken it will be assigned the same number as the sample being checked, with the addition of a letter suffix. For example, if sample number 38 failed to meet specifications, the first check sample would be numbered 38-A, the second check sample would be 38-B.

METHODS OF SAMPLING AND TESTING
MT 219-04
METHOD OF TEST FOR
CONTROLLING THE COMPACTION OF SURFACING AGGREGATES
AND PLANT MIX PAVING
USING A CONTROL-STRIP TEST-SECTION TECHNIQUE WITH NUCLEAR GAUGES
(Montana Test Method)

1 Scope:

1.1 This test method is intended to control the density of compacted courses of surfacing aggregates and plant mix pavement using nuclear gauges.

2 Referenced Documents:

2.1 ***MT Manual:***
MT-212 Determination of Moisture and Density of In-Place Materials
MT-230 Moisture-Density Relations of Soils using a 10 lb. Rammer
MT-311 Marshall Method for Field Control of Hot Mix Asphalt Paving

3 Definitions:

3.1 *Control-Strip A - Surfacing Aggregates* - A section approximately three hundred (300) feet long by the typical section width of two lanes on a firm sub-grade.

3.2 *Control-Strip B - Plant Mix Paving* - A section approximately three hundred (300) feet long by one paver width on a firmly compacted base. Please refer to table 1 on page 4 as a guide for maximum rolling times.

3.3 *Test-Section Surfacing Aggregates* - Individual sections each approximately two thousand (2000) feet long, as constructed, on which the surfacing aggregates will be placed, using the same layer thickness, compaction watering and procedures used in constructing the Control-strip A above.

3.4 *Test-Section Plant Mix Paving* - Individual sections each approximately two thousand (2000) feet long by one paver width on which plant mix material will be placed, using the same layer thickness, compaction and procedure used in construction the Control-strip B above.

4 Equipment:

4.1 Nuclear Moisture/Density Gauges - Refer to MT-212 of the Materials Manual for a description of the various types of devices.

5 Operational Procedures:

5.1 *Control-Strip Surfacing Aggregates* - At the beginning of compaction operations, the density requirements shall be determined by compacting a Control-Strip of an approved thickness. The procedure, MT-230 (Proctor Test) establishes the dry density for aggregates being used in the Control-strip. (Note 1)

Note 1 - The moisture-density of the control strip will be determined by the use of approved nuclear equipment under field conditions.

5.1.1 After each application of the roller, wet density and moisture determinations are made with the Nuclear device at a minimum of three (3) random locations. These locations may be marked with a small quantity of minus 30 mesh dry sand - the finer the better. This sand should be screened from the material that is being compacted and dried to constant weight. This sand serves to

5 Operational Procedures: (continued)

identify each test location and is an aid for seating the Nuclear device to preclude air voids between the bottom surface of the probe and the coarser aggregate particles that may be extruding above the surface of the lift. To avoid any errors in reading due to the build-up of sand beneath the Nuclear device, approximately the same quantity of sand is used at each of the three test locations. The test locations are marked so that the same locations are tested after each pass.

5.1.2 An average dry density is computed and plotted on a chart of dry density versus the number of roller passes. Rolling is discontinued when the curve plotted for dry density versus roller passes levels off. When the density plot levels off, density and moisture readings are taken at seven additional locations. Ten test sites in the 300 feet long Control-Strip are calculated to yield satisfactory statistical results. The average dry density is computed from the ten sets of readings and this serves as the standard of compaction. A new Control-Strip is required when the aggregate characteristics change appreciably, the aggregate is produced from a different source, or there has been a change in the rolling equipment or procedures used. Each new lift will require a new Control-Strip to determine if there is any change in Control-Strip density. If a different Nuclear device is used, a new Control-Strip might have to be established.

5.2 *Test-Sections Surfacing Aggregates* - The remainder of the project is divided into Test-Sections described above. After placing and compacting a lift of surfacing aggregate, employing the same thickness and procedures used in the Control-Strip, moisture and density readings are taken at ten randomly selected locations. Dry density determinations are made for each set of readings.

5.2.1 Whenever the minimum density results are not met, immediate corrective action must be taken by additional rolling or additional water and rolling. The densities of the completed Test-Sections must be determined without delay for applicable comparison (under the same conditions) with the Control-Strip density. (Note 2) Similarly, proper use of the most suitable roller can decrease time in attaining proper density in the Test-Section. The contractor should be encouraged to use various methods in establishing density in the Control-Strip.

Note 2 - (Not a specification requirement) The effective use of water and the method used in compacting the Control-Strip can influence the time and the compactive effort required to attain satisfactory density.

5.3 *Control Strip Plant Mix Paving* - All roller equipment will be approved by the engineer prior to the construction of the Control-Strip as specified in the Standard Specification. Whenever a Control-Strip is required on plant mix surfacing a comparison will be made between the established Control-Strip density and the Marshall density as determined by MT-311 (Marshall Method of Hot Mix Asphalt Paving). This should be done to ensure a reasonable Control-Strip density is established.

5.3.1 Three test sites will be randomly selected on the Control-Strip. Each site will be marked with minus 30 mesh dry seating sand used to seat the Nuclear gauge. This sand should be screened from the material that is being compacted and dried to constant weight. Compaction of the Control-Strip shall commence as soon as possible after placement of the bituminous mixture and be uniform over the entire Control-Strip before the temperature of the mix falls below 175 F. A test will be taken on each test site with a Nuclear gauge after each pass of the compaction equipment.

5.3.2 This procedure will continue until the density increase is less than one (1) pound per cubic foot at a temperature greater than 175 F. After completion of the rolling, then two more tests sites are established so that a total of five density tests are averaged for the Control-Strip density.

5.3.3 Each new lift will require a new Control-Strip to determine if there is any change in Control-Strip density. If a different Nuclear device is used, a new Control-Strip might have to be established.

5 Operational Procedures: (continued)

5.4 *Test Section Plant Mix Paving* - The remainder of the project is divided into 2000 ft. test sections. After placing and compacting a lift of Plant Mix Paving, employing the same thickness and procedures used in the Control-Strip, density readings are taken at five randomly selected locations. The average density of each test section will be evaluated based upon the results of five tests in each test section. Whenever the minimum density results are not met, immediate corrective action must be taken by additional rolling. The densities of the completed test sections must be determined without delay for applicable comparison (under the same conditions) with the Control-Strip density.

6 Forms and Reports:

6.1 The attached Lab. Form No. 1000-A is used for controlling the compaction of surfacing aggregates. This form may also be used for Control Strip paving.

6.2 Lab. Form No. 1006-A, Summary of Compaction Data for Surfacing, is applicable for all types of Nuclear devices. It is requested that the serial number of the device being used and the Laboratory Number of each pit, be entered on this form.

TABLE 1*

MAXIMUM AVAILABLE ROLLING TIMES

Recommended Minimum Laydown Temperature

	Mat Thickness					
Base Temp.°F	½"	3/4"	1"	1-1/2"	2"	3" and Greater
+35-40	-	-	-	305	295	280
+40-50	-	-	310	300	285	275
+50-60	-	310	300	295	280	270
+60-70	310	300	290	285	275	265
+70-80	300	290	285	280	270	265
+80-90	290	280	275	270	265	260
+90	280	275	270	265	260	255
Maximum Available Rolling time, minutes.	4	6	8	12	15	15

* Table from Superintendents Manual on Compaction of Hot Mix Asphalt Pavement

As an example: to illustrate the use of the table, assume we are placing a 1½" thick mat and the base temperature is between 50°F and 60°F. A laydown temperature of 295°F is needed to provide 12 minutes before the mat cools to an average temperature of 175°F. If it is a warmer day, with a base temperature of 70°F to 80°F, a laydown temperature of 280°F would provide 12 minutes of rolling time. On a day warm enough to have a base temp of 70°F to 80°F, the air temperature would probably be above 40°F and there would be some sunshine, so it would probably take 2 or 3 more minutes to cool to 175°F, probably 15 minutes.

Where dashes appear in the table, conditions are such that it is doubtful that specification density can be achieved so work would cease. The table has come to be known as "cessation requirements."

Control Strip Density

Gauge Serial No. _____

Project No._____ Control Strip No._____ Type of Material_____ Pit No._____

Test Site Number	Density Ref. Standard Count	Moisture Ref. Standard Count	Backscatter Count	Direct Tran. Count and Depth	Moisture Wet Density	Location	Distance Left or Right of Centerline	☐ PCF ☐ Kg/cu. m	Percent Moisture	Dry Density
1										
2										
3										
1										
2										
3										
1										
2										
3										
1										
2										
3										
1										
2										
3										
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
							TOTAL			
							AVERAGE			

Density as determined by this control strip_____ x .98 =_____ (Mean density requirement)
Density as determined by this control strip_____ x .95 =_____ (Individual density requirement)
Remarks:

METHODS OF SAMPLING AND TESTING
MT 220-04
SPECIFIC GRAVITY OF SOILS
(Modified AASHTO T100)

1 Scope:

1.1 This method covers determination of the specific gravity of soils by means of a pycnometer. When the soil is composed of particles larger than the 4.75 mm (No. 4) sieve, the method outlined in MT-205, Test for Specific Gravity and Absorption of Coarse Aggregate, shall be followed. When the soil is composed of particles both larger and smaller than the 4.75 mm sieve, the sample shall be separated on the 4.75 mm sieve and the appropriate test method used on each portion. The specific gravity value for the soil shall be the weighted average of the two values (Note 1). When the specific gravity value is to be used in calculations in connection with the hydrometer portion of AASHTO T 88, Particle-Size Analysis of Soils, it is intended that the specific gravity test be made on that portion of the soil that passes the 2.00 mm (No. 10) sieve.

1.2 The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value.

Note 1- The weighted average specific gravity should be calculated using the following equation:

$$G_{avg} = \frac{1}{\frac{R_1}{100G_1} + \frac{P_1}{100G_2}}$$

where:

G_{avg} = weighted average specific gravity of soils composed of particles larger and smaller than the 4.75 mm (No. 4) sieve,

R_1 = percent of soil particles retained on the 4.75 mm sieve,

P_1 = percent of soil particles passing the 4.75 mm sieve,

G_1 = apparent specific gravity of soil particles retained on the 4.75 mm sieve as determined by MT-205, and

G_2 = specific gravity of soil particles passing the 4.75 mm sieve as determined by this test method.

1.3 The values stated in acceptable metric units are to be regarded as the standard.

1.4 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Referenced Documents:

2.1 ***AASHTO:***

T 2 Sampling Aggregates
T 88 Particle Size Analysis of Soils
T 100 Specific Gravity of Soils

2 Referenced Documents: (continued)

2.2 ***MT Manual:***
MT-200 Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Tests
MT-205 Specific Gravity and Absorption of Coarse Aggregate
MT-405 Wire Cloth Sieves for Testing Purposes
MT-407 Reducing Field Samples of Aggregate to Testing Size

2.2 ***ASTM:***
C 670 Practice for Preparing Precision Statements for Test Methods for Construction Materials
E 12 Definition of Terms Relating to Density and Specific Gravity of Solids, Liquids, and Gases

3 Definition:

3.1 *Specific Gravity*--the ratio of the mass in air of a given volume of a material at a stated temperature to the mass in air of the same volume of gas free distilled water at a stated temperature (per Definition E 12).

4 Apparatus:

4.1 The apparatus shall consist of the following:

4.1.1 *Pycnometer* - Either a volumetric flask having a capacity of at least 100 ml or a stoppered bottle having a capacity of at least 50 ml (Note 2). The stopper shall be of the same material as the bottle, and of such size and shape that it can be easily inserted to a fixed depth in the neck of the bottle, and shall have a small hole through its center to permit the emission of air and surplus water.

Note 2 - The use of either the volumetric flask or the stoppered bottle is a matter of individual preference, but in general, the flask should be used when a larger sample than can be used in the stoppered bottle is needed due to maximum grain size of the sample.

4.1.2 *Balance* - A balance having a capacity of 1 kilogram or more and sensitive to 0.001 gram or less.

4.1.3 *Oven* - A thermostatically controlled drying oven capable of maintaining a temperature of 110 ± 5°C (230 ± 9°F).

4.1.4 *Thermometer* - A thermometer covering the range of 0-50°C (32-122°F), readable and accurate to 1°C (2°F).

5 General Requirements for Weighing:

5.1 When the volumetric flask is used in the specific gravity determination, all masses shall be determined to the nearest 0.01 g. When the stoppered bottle is used in the specific gravity determination, all masses shall be determined to the nearest 0.001 g.

6 Calibration of Pycnometer:

6.1 The pycnometer shall be cleaned, dried, weighed, and the mass recorded. The pycnometer shall be filled with distilled water (Note 3) essentially at room temperature. The mass of the pycnometer and water, W_a, shall be determined and recorded. A thermometer shall be inserted in the water and its temperature, T_i determined to the nearest whole degree.

Note 3 - Kerosine is a better wetting agent than water for most soils and may be used in place of distilled water for oven-dried samples.

6 Calibration of Pycnometer: (continued)

6.2 From the mass W_a determined at the observed temperature T_i a table of values of mass W_a shall be prepared for a series of temperatures that are likely to prevail when masses W_b are determined later (Note 4). These values of W_a shall be calculated as follows:

W_a (at T_x) = (density of water at T_x/density of water at T_i) X (W_a(at T_i) - W_f) + W_f

where:

W_a = mass of pycnometer and water, in grams,

W_f = mass of pycnometer, in grams,

T_i = observed temperature of water, in degrees Celsius, and

T_x = any other desired temperature, in degrees Celsius.

Note 4 - This method provides a procedure that is most convenient for laboratories making many determinations with the same pycnometer. It is equally applicable to a single determination. Bringing the pycnometer and contents to some designated temperature when masses W_a and W_b are taken, requires considerable time. It is much more convenient to prepare a table of masses W_a for various temperatures likely to prevail when masses W_b are taken. It is important that masses W_a and W_b be based on water at the same temperature. Values for the relative density of water at temperatures from 18 to 30°C are given in Table 1.

TABLE 1 Relative Density of Water and Conversion Factor K for Various Temperatures

Temperature, deg C	Relative Density of Water	Correction Factor K
18	0.9986244	1.0004
19	0.9984347	1.0002
20	0.9982343	1.0000
21	0.9980233	0.9998
22	0.9978019	0.9996
23	0.9975702	0.9993
24	0.9973286	0.9991
25	0.9970770	0.9989
26	0.9968156	0.9986
27	0.9965451	0.9983
28	0.9962652	0.9980
29	0.9959761	0.9977
30	0.9956780	0.9974

7 Sample:

7.1 The soil to be used in the specific gravity test may contain its natural moisture or be oven-dried. The mass of the test sample on an oven-dry basis shall be at least 25 g when the volumetric flask is to be used, and at least 10 g when the stoppered bottle is to be used.

7.2 *Samples Containing Natural Moisture* - When the sample contains its natural moisture, the mass of the soil, W_a, on an oven-dry basis shall be determined at the end of the test by evaporating the water in an oven maintained at 110 ± 5°C (230 ± 9°F) (Note 5). Samples of clay soils containing their natural moisture content shall be dispersed in distilled water before placing in the flask, using the dispersing equipment specified in AASHTO T 88 (Note 6).

7.3 *Oven-Dried Samples* - When an oven-dried sample is to be used, the sample shall be dried for at least 12 h, or to constant mass, in an oven maintained at 110 ±5°C (230 ± 9°F)(Note 5), cooled to room temperature, then weighed and transferred to pycnometer or transferred to pycnometer then weighed. Distilled water shall be added into pycnometer in an amount that will provide complete sample coverage. The sample shall then soak for at least 12 h.

Note 5 - Drying of certain soils at 110°C may bring about loss of moisture of composition or hydration, and in such cases drying shall be done, if desired, in reduced air pressure and at a lower temperature.

Note 6 - The minimum volume of slurry that can be prepared by the dispersing equipment specified in AASHTO T 88 is such that a 500-ml flask is needed as the pycnometer.

8 Procedure:

8.1 The sample as prepared in Section 7 shall have distilled water added to fill the volumetric flask about three-fourths full or the stoppered bottle about half full.

8.2 Remove entrapped air by either of the following methods: (1) subject the contents to a partial vacuum of 100 mm Hg or less absolute pressure or (2) boil gently for at least 10 min., while occasionally rolling the pycnometer to assist in the removal of the air. Subjection of the contents to reduced air pressure may be done either by connecting the pycnometer directly to an aspirator or vacuum pump, or by use of a bell jar. Some soils boil violently when subjected to reduced air pressure. It will be necessary in those cases to reduce the air pressure at a slower rate or to use a larger flask (Note 7). Samples that are heated shall be cooled to room temperature.

Note 7 - When using partial vacuum agitate the flask gently at intervals during the evacuation process. (A) Samples containing natural moisture with high plasticity may require 6 to 8 hours to remove air; samples with low plasticity may require 4 to 6 hours to remove air. (B) Oven-dried samples may require 2 to 4 hours to remove air.

8.3 Fill the pycnometer with distilled water to its calibrated capacity, clean the outside and dry with a clean, dry cloth. Determine the mass of the pycnometer and contents W_b, and the temperature in degrees Celsius, T_x, of the contents as described in Section 6.

9 Calculation and Report:

9.1 Calculate the specific gravity of the soil, based on water at a temperature T_x, as follows:

specific gravity, $T_x/T_x = W_o/[W_o + (W_a - W_b)]$

where:

W_o = mass of sample of oven-dried soil in grams.

W_a = mass of pycnometer filled with water at temperature T_x, (Note 8)in grams, and

9 Calculation and Report: (continued)

T_x = temperature of the contents of the pycnometer when mass W_b was determined, in degrees Celsius.

Note 8 - This value shall be taken from the table of values of W_a, prepared in accordance with 7.2 for the temperature prevailing when mass W_b was taken.

9.2 Unless otherwise required, specific gravity values reported shall be based on water at 20°C. The value based on water at 20°C shall be calculated from the value based on water at the observed temperature T_x, as follows:

Specific gravity, $T_x/20°C = K$ X specific gravity, T_x/T_x

where:

K = a number found by dividing the relative density of water at temperature T_x by the relative density of water at 20°C. Values for a range of temperatures are given in Table 1.

9.3 When it is desired to report the specific gravity value based on water at 4°C, such a specific gravity value may be calculated by multiplying the specific gravity value at temperature T_x by the relative density of water at temperature T_x.

9.4 When any portion of the original sample of soil is eliminated in the preparation of the test sample, the portion on which the test has been made shall be reported.

9.5 When using the volumetric flask to determine specific gravities, report results to at least the nearest 0.01.

9.6 When using the stoppered bottle to determine specific gravities, report results to at least the nearest 0.001.

METHODS OF SAMPLING AND TESTING
MT 223-04
METHOD OF TEST FOR CLAY LUMPS AND FRIABLE PARTICLES IN AGGREGATES
(Modified AASHTO T 112)

1 Scope:

1.1 This method covers the approximate determination of clay lumps and friable particles in natural aggregates.

1.2 This standard may involve hazardous materials, operations and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of whoever uses this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Referenced Documents:

2.1 ***AASHTO:***
T 112 Clay Lumps and Friable Particles in Aggregate

MT Manual:
MT 202 Sieve Analysis of Fine and Coarse Aggregate
MT-405 Sieves for Testing Purposes

3 Apparatus:

3.1 *Balances* - Balances or scales for determining the mass of the test samples shall be sensitive to 0.1 percent of the mass of the sample. The residue (Section 5) shall be weighed on a balance or scale sensitive to 0.02 percent of the mass of the original test sample.

3.2 *Containers* - Rust-resistant containers of a size and shape that will permit the spreading of the sample on the bottom in a thin layer.

3.3 *Sieves* - Sieves conforming to MT-405, Sieves for Testing Purposes.

3.4 *Oven* - Oven capable of maintaining a temperature of 230 ± 9°F (110 ± 5°C).

4 Samples:

4.1 The aggregate shall be dried to substantially constant mass at a temperature of 230 ± 9°F (110 ± 5°C).

4.2 Test samples of fine aggregate shall consist of particles coarser than a 1.18 mm (No.16) sieve and shall weigh not less than 450 grams.

4.3 Test samples of coarse aggregate shall be separated into different sizes, using the following sieves: 4 Mesh (4.75 mm), 3/8 in. (9.5 mm), 3/4 in. (19.0 mm), and 1½ in. (37.5 mm). The test sample shall weigh not less than indicated in the following table:

4 **Samples:** (continued)

Size of Particles Making up Sample	Minimum Mass of Test Sample, Min, g.
4-M to 3/8 in. (4.75 to 9.5 mm)	1000
3/8 to 3/4 in. (9.5 to 19.0 mm)	2000
3/4 to 1½ in. (19.0 to 37.5 mm)	3000
Over 1½ in. (37.5 mm)	5000

4.4 If the grading of the original sample provides less than 5% of any of the sizes indicated in Section 4.3, do not test that size.

4.5 In the case of aggregate which is composed of substantial amounts of both fine and coarse aggregate sizes, separate the material into two sizes at the 4.75 mm (No. 4) sieve, and prepare the samples of fine and coarse aggregate in accordance with sections 4.3 and 4.4. Any aggregate containing 50 percent or more material retained on the 4.74 mm (No. 4) sieve is considered to be coarse aggregate.

Note 1 – In most cases, only the plus 4.75 mm (No. 4) fraction of coarse aggregate needs to be evaluated by this test, regardless of the amount of minus 4.75 mm (No. 4) material present. However, the amount of 1.18 mm (No. 16) to 4.75 mm (No. 4) material present shall be included in the weight of the test sample in Section 5.1when calculating the percent of clay lumps and friable particles.

5 **Procedure:**

5.1 Weigh the test sample and spread it in a thin layer on the bottom of the container, cover it with water, and allow it to soak for a period of 24 ± 4 hours. Roll and squeeze particles individually between the thumb and forefinger to attempt to break particles into smaller sizes. Do not use fingernails to break up particles, or press particles against a hard surface or each other. Any particles that can be broken with the fingers into fines removable by wet sieving shall be classified as clay lumps or friable particles. After all discernible clay lumps and friable particles have been broken, separate the undersized material from the remainder of the sample by wet sieving over the sieve prescribed in the following table.

Size of Particles Making up Test Sample	Size of Sieve for Removing Residue of Clay Lumps and Friable Particles
Fine Aggregate retained on 16-M (1.18 mm)	20-M (0.850 µm)
4-M to 3/8 in (4.75 to 9.5 mm)	8-M (2.36 mm)
3/8 to 3/4 in. (9.5 to 19.0 mm)	4-M (4.75 mm)
3/4 to 1½ in. (19.0 to 37.5 mm)	4-M (4.75 mm)
Over 1½ in. (37.5 mm)	4-M (4.75 mm)

Wet sieve is to be accomplished by passing water over the sample through the sieve while manually agitating the sieve until all undersize material has been removed.

5.2 The retained particles shall be carefully removed from the sieve and dried to substantially constant mass at a temperature of 230 ± 9ºF (110 ± 5ºC), allowed to cool, and weighed to an accuracy of 0.02 percent, based on the original mass of the test sample.

6 Calculations

6.1 Calculate the percent of clay lumps and friable particles in fine aggregate or individual sizes of coarse aggregate as follows:

$P = [(M - R)/M] \times 100$

where:

P = percent of clay lumps and friable particles,

M = mass of test sample [for fine aggregate the mass of the portion coarser than the 16-m (1.18 mm) sieve as described in Sec. 4.2, and

R = mass of particles retained on designated sieve, as determined in accordance with Section 5.2.

6.2 For coarse aggregates, the percent of clay lumps and friable particles shall be an average based on the percent of clay lumps and friable particles in each sieve size fraction weighed in accordance with the grading of the original sample before separation or, preferably the average grading of the supply represented by the sample. Should the aggregate contain less than 5 percent of the material in a given size, that size shall be considered to contain the same percent of clay lumps and friable particles as the next larger or next smaller size, whichever is present.

METHODS OF SAMPLING AND TESTING
MT 225-04
PROCEDURE FOR
FAILING AND CHECK SAMPLES OF AGGREGATE

1 SCOPE:

1.1 This method defines the procedures for obtaining check samples and directs the necessary corrective action required to return failing material to acceptable limits.

1.2 It is a training requirement for new personnel sampling or testing aggregate to view the Safety and Training Bureau's slide and audio presentation, "Aggregate Gradation Testing", prior to performing this test.

2 Referenced Documents:

2.1 ***MT Manual:***
MT-201 Sampling Roadway Materials

3 Production Samples:

3.1 In general, a sample from a moving belt or a sampling device can be represented by a check sample only if the original sample has been split with a portion designated for use as a check sample. Samples taken at a later time cannot be designated as check samples since considerable production may have occurred between the time of testing the failing sample and testing of the next sample. Therefore, the second sample simply becomes another Acceptance sample and is numbered consecutively.

3.1.1 If the second sample, taken after further production, also fails, steps must be taken to halt the production of aggregate until an explanation for the failure has been found and corrective action can be taken.

3.1.2 A few examples of the possible causes for failing tests are listed below:

A hole in one or more screens in the plant.

An unrepresentative sample.

An error in the testing procedure.

An error in calculating the test results.

Testing equipment not in calibration or not meeting specifications.

A change in the physical characteristics of the material in the pit (in the case of a crushing operation).

Stockpile contamination.

A plugged feeder or plugged bins.

4 Road and Windrow Samples:

4.1 Test results from a sample of material that has been placed on the roadway can easily be checked by obtaining another sample of the material from the same location on the roadway and in the same manner as the failing sample. Check for possible causes of the failing tests as in 3.1.2, where applicable. (See MT-201, Sampling Roadway Materials). If the check samples also fail to meet specifications, an investigation must be conducted to determine the extent and seriousness of the problem.

4 Road and Windrow Samples: (continued)

Note 1 - A single check sample is not a satisfactory indication that the production of aggregate has returned to acceptable limits. At least two passing check samples must be taken.

5 Stockpile Samples:

5.1 Refer to MT-201, Section 10, for the procedure in sampling a stockpile. The most satisfactory method of determining a stockpile average is to sample and test the material at the time of crushing. If tests of stockpiled material do not meet specifications, the same investigation should be conducted as described in paragraph 3.1.2. Check samples on material taken during production of a stockpile must be a split of the original sample. Existing stockpiles can be re-sampled at a later time and that sample can be designated as a check sample.

6 Plant Mix Aggregate:

6.1 Production test numbering will begin and continue as long as the sample is from material being incorporated into the work. These are acceptance samples.

6.2 Tests which are run to monitor operations adjustments, while the material being sampled is not to be incorporated into the work, shall be labeled and numbered as "Non-production #1," "Non-production #2," etc. Only those tests run a split of the same sample

6.3 Only those tests run on a split of the same sample will be designated as check samples.

7 Numbering Check Samples:

7.1 When a check sample is taken it will be assigned the same number as the sample being checked, with the addition of a letter suffix. For example, if sample number 38 failed to meet specifications, the first check sample would numbered 38-A, the second check sample would be 38-B, etc.

8 Other Samples:

8.1 Usually check tests on the materials not listed above are covered in the specific methods for the materials being tested.

9 Remarks:

9.1 The person with the responsibility for sampling and testing aggregates shall, in the case of failing tests, remark on the work sheet, or summary, the corrective action taken to resolve the problem.

METHODS OF SAMPLING AND TESTING
MT 226-04
MAXIMUM ACCEPTABLE DEVIATIONS
IN THE SIEVE ANALYSIS OF INDEPENDENT ASSURANCE SAMPLES
(MONTANA METHOD)

1 Scope:

1.1 The charts included in this method shall serve as a guide in evaluating the maximum acceptable deviations in the sieve analysis of Independent Assurance samples. If the individual grading percentages vary from the group average percentages by more than the amounts listed, the cause must be determined and the error remedied. Deviation percentages are based on the weight of the total sample.

2 References:

2.1 ***MT Manual:***
MT-201 - Preparing the Three-way Split Samples for Test and the Responsibility for Investigating Discrepancies.
MT-417 - Method for Splitting or Quartering.
MT-602 - The Federal Highway Administration Policy and Procedure for Sampling and Testing Independent Assurance and Final Record Samples.

Note 1 - The specifications apply to the material while the permissible deviation is used only to compare sieve analysis obtained in the field, division or area laboratory and Materials Bureau.

FINE AGGREGATE FOR CONCRETE

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES		
Sieve Size	Percent Passing	Permissible Variation
3/8" (9.5 mm)	100	- 2%
No. 4 (4.75 mm)	95 - 100	± 2%
No. 8 (2.36 mm)	80 - 100	± 2%
No. 16 (1.18 mm)	50 - 85	± 2%
No. 30 (0.600 µm)	25 - 60	± 2%
No. 50 (0.300 µm)	5 - 30	± 2%
No. 100 (0.150 µm)	0 - 10	± 2%
No. 200 (0.075 µm)	0 - 3	± 2%

COARSE AGGREGATE FOR CONCRETE

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES				
GRADATION	No. 1	No. 2	No. 3	No. 4
Sieve Size	1 1/2" to No. 4	3/4 " to No. 8	1 1/2" to 3/8"	1/2" to No. 8
2" (50 mm)	100 - 2%		100 - 2%	
1 1/2" (37.5 mm)	95 - 100 ± 3%		90 - 100 ± 3%	
1" (25 mm)		100 - 2%	20 - 55 ± 3%	
3/4" (19 mm)	35 - 70 ± 3%	90 - 100 ± 3%	0 - 15 ± 3%	100 - 2%
1/2" (12.5 mm)				90 - 100 ± 3%
3/8" (9.5 mm)	10 - 30 ± 2%	20 - 55 ± 2%	0 - 5 ± 2%	40 - 70 ± 2%
No. 4 (4.75 mm)	0 - 5 ± 2%	0 - 10 ± 2%		0 - 15 ± 2%
No. 8 (2.36 mm)		0 - 5 ± 2%		0 - 5 ± 2%

SELECTED SURFACING

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES						
Sieve Size	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
4" (100 mm)	100 - 2%					
3" (75 mm)		100 - 2%				
2 1/2" (63 mm)			100 - 2%			
2 A (50 mm)				100 - 2%		
1 1/2" (37.5 mm)					100 - 2%	
1" (25 mm)						100 - 2%
No. 200 (75 µm)	15 max ± 1.5%	15 max ± 1.5%	15 max ± 1.5%	15 max ± 1.5%	15 max ± 1.5%	15 max ± 1.5%

SAND SURFACING

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES					
Sieve Size	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
1 2" (37.5 mm)	100 - 2%				
1" (25.0 mm)		100 - 2%			
3/4" (19.0 mm)			100 - 2%		
1/2" (12.5 mm)				100 - 2%	
No. 4 (4.75 mm)					100 - 2%
No. 10 (2.00 mm)	65 min ± 2%	65 min ± 2%	65 min ± 2%	50 min ± 2%	50 min ± 2%
No. 200 (75 µm)	20 max ±1.5%	20 max ±1.5%	20 max ±1.5%	20 max ±1.5%	20 max ±1.5%

CRUSHED TOP SURFACING, TYPE "A"

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES					
Sieve Size	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5
1" (25 mm)	100 - 2%				
3/4" (19.0 mm)		100 - 2%			
5/8" (16.0 mm)			100 - 2%		
1/2" (12.5 mm)				100 - 2%	
3/8" (9.5 mm)					100 - 2%
No. 4 (4.75 mm)	40 - 70 ± 2%	40 - 70 ± 2%	40 - 70 ± 2%	40 - 70 ± 2%	50 - 80 ± 2%
No. 10 (2.00 mm)	25 - 55 ± 2%	25 - 55 ± 2%	25 - 55 ± 2%	25 - 60 ± 2%	35 - 70 ± 2%
No. 200 (75 µm)	2 – 10 ± 1.5%	2 - 10 ± 1.5%	2 - 10 ± 1.5%	2 - 10 ± 1.5%	2 - 10 ± 1.5%

CRUSHED TOP SURFACING, TYPE "B"

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES			
Sieve Size	Grade 1	Grade 2	Grade 3
1 1/2" (37.5 mm)	100 - 2%		
1" (25 mm)		100 - 2%	
3/4" (19.0 mm)			100 - 2%
1/2" (12.5 mm)			
No. 4 (4.75 mm)	40 - 80 ± 2%	40 - 80 ± 2%	40 - 80 ± 2%
No. 10 (2.00 mm)	25 - 60 ± 2%	25 - 60 ± 2%	25 - 60 ± 2%
No. 200 (75 µm)	5 - 20 ± 1.5%	5 - 20 ± 1.5%	5 - 20 ± 1.5%

CRUSHED BASE COURSE, TYPE "A"

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES		
Sieve Size	Grade 5	Grade 6
2" (50 mm)	100 - 2%	
1/2" (37.5 mm)	95 - 100 ± 2%	100 - 2%
3/4" (19.0 mm)	70 - 89 ± 2%	75 - 95 ± 2%
3/8" (9.5 mm)	50 - 70 ± 2%	40 - 75 ± 2%
No. 4 (4.75 mm)	35 - 58 ± 2%	25 - 60 ± 2%
No. 40 (425 µm)	9 - 30 ± 2%	13 - 34 ± 2%
No. 200 (75 µm)	8 max ± 1.5%	8 max ± 1.5%

CRUSHED BASE COURSE, TYPE "B"

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES			
Sieve Size	Grade 1	Grade 2	Grade 3
2" (50 mm)	100 - 2%		
1 2" (37.5 mm)		100 - 2%	
1" (25 mm)	50 - 80 ± 2%		100 - 2%
No. 4 (4.75 mm)	20 - 50 ± 2%	25 - 55 ± 2%	30 - 60 ± 2%
No. 10 (2.00 mm)			20 - 50 ± 2%
No. 200 (75 µm)	8 max ± 1.5%	8 max ± 1.5%	8 max ± 1.5%

COVER MATERIAL

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES					
Sieve Size	Grade 1A	Grade 2A	Grade 3A	Grade 4A	Grade 5A
5/8" (16.0 mm)	100 - 2%				
1/2" (12.5 mm)		100 - 2%	100 - 2%		
3/8" (9.5 mm)	33 - 55 ± 2%	40 - 90 ± 2%	95 - 100 ± 2%	100 - 2%	100 - 2%
No. 4 (4.75 mm)	0 - 15 ± 2%	0 - 15 ± 2%	0 - 30 ± 2%	0 - 30 ± 2%	9 - 50 ± 2%
No. 8 (2.36 mm)	0 - 5 ± 2%	0 - 5 ± 2%	0 - 15 ± 2%	0 - 15 ± 2%	2 - 20 ± 2%
No. 200 (75 µm)	2 max ± 1.5%	2 max ± 1.5%	2 max ± 1.5%	2 max ± 1.5%	2 max ± 1.5%

AGGREGATE FOR CEMENT-TREATED BASE

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES	
Sieve Size	Job Mix Target Limits
3/4" (19.0 MM)	100 - 2%
No. 4 (4.75 mm)	40 - 70 ± 2%
No. 10 (2.00 mm)	25 - 55 ± 2%
No. 200 (75 µm)	4 - 12 ± 1.5%

FILTER MATERIAL

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES		
Sieve Size	Gradation No. 1	Gradation No. 2
2" (50 mm)		100 - 2%
11/2" (37.5 mm)		95 - 100 ± 3%
3/4" (19.0 mm)		35 - 70 ± 3%
3/8" (9.5 mm)	100 - 2%	10 - 30 ± 2%
No. 4 (4.75 mm)	95 - 100 ± 2%	5 max ± 2%
No. 8 (2.36 mm)	80 - 100 ± 2%	
No. 16 (1.18 mm)	50 - 85 ± 2%	
No. 30 (600 µm)	25 - 60 ± 2%	
No. 50 (300 µm)	5 - 30 ± 2%	
No. 100 (150 µm)	10 max ± 1.5%	

PLANT MIX SURFACING

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES			
Sieve Size	Grade "A"	Grade "B"	Grade "D"
3/4" (19.0 mm)	100 - 2%	100 - 2%	100 - 2%
1/2" (12.5 mm)	87 - 93 ± 2%	86 - 90 ± 2%	79 - 83 ± 2%
3/8" (9.5 mm)	77 - 83 ± 2%	75 - 79 ± 2%	68 - 72 ± 2%
No. 4 (4.75 mm)	52 - 58 ± 2%	53 - 57 ± 2%	44 - 50 ± 2%
No. 10 (2.00 mm)	36 - 41 ± 2%	34 - 40 ± 2%	27 - 33 ± 2%
No. 40 (0.425 mm)	19 - 21 ± 2%	16 - 18 ± 2%	12 - 15 ± 2%
No. 200 (75 µm)	6 - 8 ± 1.5%	5 - 7 ± 1.5%	4.5 - 6.5 ± 1.5%

BEDDING MATERIAL

PERCENTAGE BY WEIGHT PASSING SQUARE MESH SIEVES	
Sieve Size	Percent Passing
4" (100 mm)	100 - 2%
No. 4 (4.75 mm)	25 - 60 ± 2%
No. 200 (75µm)	0 - 12 ± 1.5%

METHODS OF SAMPLING AND TESTING
MT 227-04
METHOD OF TEST FOR LABORATORY DETERMINATION OF MOISTURE CONTENT OF SOILS (MODIFIED AASHTO T 265)

1 Scope:

1.1 This method covers the laboratory determination of the moisture content of soils.

1.2 The following applies to all specified limits in this standard: For the purposes of determining conformance with theses specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right-hand place of figures used in expressing the limiting value, in accordance with AASHTO R 11.

2 Referenced Documents:

2.1 *AASHTO:*
T 265 Laboratory Determination of Moisture Content of Soils

3 Definition:

3.1 *Moisture or Water Content of Soil* – The ratio, expressed as a percentage, of the mass of water in a given mass of soil to the mass of the solid particles. Practical application is to determine the mass of water removed by drying the moist soil to a constant mass in a drying oven controlled at 110 ± 5ºC (230 ± 9ºF) and to use this value as the mass of water in the given soil mass. The mass of the soil remaining after oven drying is used as the mass of the solid particles.

4 APPARATUS:

4.1 *Drying Oven* – thermostatically controlled, preferably of the forced-draft type, capable of being heated at a temperature of 110 ± 5ºC (230 ± 9ºF).

4.2 *Balance* – The balance shall have sufficient capacity, be readable to 0.1 percent of the sample mass, or better, and conform to the requirements of AASHTO M 231.

4.3 *Containers* – Suitable containers made of material resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. Containers shall have close fitting-lids to prevent loss of moisture from samples before initial weighing and to prevent absorption of moisture from the atmosphere following drying and before final weighing. One container is needed for each moisture content determination.

5 Test Sample:

5.1 Select a represenitive quantity of moist soil in the amount indicated in the method of test. If no amount is indicated, the minimum mass of the sample shall be in accordance with the following table:

Maximum Particle Size	Minimum Mass of Sample, g
0.425- mm (No. 40 sieve)	10
4.75-mm (No. 4 sieve)	100
12.5-mm (1/2 in.)	300
25.0-mm (1 in.)	500
50-mm (2 in.)	1000

6 Procedure:

6.1 Weigh a clean, dry container with its lid, and place the moisture content sample in the container. Replace the lid immediately, and weigh the container, including the lid and moist sample. Remove the lid and place the container with the moist sample in the drying oven maintained at a temperature of 110 ± 5°C (230 ± 9°F) and dry to a constant mass (Notes 1 and 2). Immediately upon removal from the oven, place the lid on the container and allow the sample to cool to room temperature. Weigh the container including the lid and the dried sample (Notes 3 and 4).

Note 1 – Checking every moisture content sample to determine that it is dried to a constant mass is impractical. In most cases, drying of a moisture content sample overnight (15 or 16 hours) is sufficient. In cases where there is no doubt concerning the accuracy of overnight drying, drying should be continued until the mass after two successive periods of drying indicates no change in mass. Samples of sand may often be dried to constant mass in a period of several hours. Since dry soil may absorb moisture from wet samples, dried samples should be removed before placing wet samples in the oven.

Note 2 – Oven-drying at 110 ± 5°C (230 ± 9°F) does not result in reliable moisture content values for soil containing gypsum or other minerals having loosely bound water from hydration or for soil containing significant amounts of organic material. Reliable moisture content values for these soils can be obtained by drying in an oven at approximately 60°C (140°F), or by vacuum desiccation at a pressure of approximately 10 mm Hg and at a temperature not lower than 23°C (73°F).

Note 3 – A container without a lid may be used provided the moist sample is weighed immediately after being taken and providing the dried sample is weighed immediately after being removed from the oven or after cooling in a desiccator.

Note 4 – Moisture content samples should be discarded and should not be used in any other tests.

7 CALCULATION:

7.1 Calculate the moisture content of the soil as follows:

w = [(mass of moisture)/(mass of oven-dry soil)] x 100 = $[(W_1 - W_2)/(W_2 - W_c)]$ x 100

where:

w = moisture content, percent,

W_1 = moisture content and moist soil, g,

W_2 = mass of container and oven-dried soil, g, and

W_c = mass of container, g.

7.2 Calculate the percent of moisture content to the nearest 0.1 percent.

METHOD OF SAMPLING AND TESTING
MT 228-04
METHOD OF TEST FOR
EVALUATING CLEANNESS OF COVER COAT MATERIAL
(MONTANA METHOD)

1 Scope:

1.1 The cleanness test indicates the relative amount, fineness, and character of clay-like materials present in aggregate as coatings or otherwise.

2 Apparatus:

2.1 Funnel – A funnel to hold nested No. 8 or No. 10 and No. 200 sieves at the large end and necked down to rest in a 500 ml graduated cylinder at the small end.

2.2 Jars - One-gallon, Wide-mouth jars with lids and rubber gaskets.

2.3 Graduated cylinder - Graduated glass or plastic cylinders of 10 ml and 500 ml capacities.

2.4 Sieves - Sieves of the following sizes, U.S. Standard No. 8, No. 10, and No. 200.

2.5 Balance - A balance or scale sensitive to one gram with a capacity of 2610 grams.

2.6 Splitter – A sample splitter suitable for dividing filed samples into test portion sizes according to MT-417.

2.7 Spatula – A spatula approximately 7 inches (177.8 mm) long and ½ inch (12.7 mm) wide.

2.8 Sand equivalent stock solution. (Refer to MT-213).

2.9 Sand equivalent cylinder, rubber stopper, and timing device.

2.10 Syringe or spray attachment.

2.11 Spatula, approximately 7 in. (177.8 mm) long and ½ in. (12.7 mm) wide.

3 Preparation of Sample:

3.1 To eliminate contamination of the sample, a clean sack should be used (preferably a new sack).

3.2 Place the entire sample on a clean, dry surface.

3.3 Shake all the dust from the sack and combine with the sample.

3.4 When the sample is dry, quarter the sample to approximately 5 lbs. (2.3 kg).

3.5 Split the 5 lb. (2.3 kg) sample down to the required 1000 ± 50 grams. All of the dust particles must be cleaned from the splitting device and added to the appropriate sample.

Note 1 – This test may be normally performed without strict temperature control. Use distilled or demineralized water for the normal performance of the test. This is necessary because certain minerals dissolved in water affect the test results. It is permissible to use local tap water if it is determined that the water is of such purity that it does not affect the test results. However, in the event of dispute, retest the material using distilled or demineralized water at a temperature with the temperature of the wash solution at 72° ± 5° F (22 ± 3°C).

3 Preparation of Sample: (continued)

Note 2 – Use distilled or demineralized water for the normal performance of the cleanness test. This is necessary because certain minerals dissolved in water affect the test results. However, if it is determined that the local tap water is of such purity that it does not effect the test results, it is permissible to use it in lieu of distilled or demineralized water except in the event of dispute.

4 Test Procedure:

4.1 Place the sand equivalent cylinder on a worktable that will not be subjected to vibrations during the performance of the sediment phase of the test.

4.2 Pour 7 ml of the stock solution into the cylinder.

4.3 Nest the two sieves; with the No. 8 or No. 10 on the top, in the large funnel that in turn rests on the 500 ml graduate. The No. 8 or No. 10 sieve serves only to protect the No. 200 sieve.

4.4 Place the prepared sample in the one-gallon jar. Add only enough water to completely cover the aggregate and cap tightly.

4.5 Begin agitation after one minute from the introduction of the water. The agitation procedure is described as follows:

4.5.1 While holding the jar vertically with both hands, the washing shall be done with an arm motion that causes the jar to describe a circle with approximately a 6-inch radius. See Figure 1. The jar may be held either by the sides or by the top and bottom, whichever is more convenient.

4.5.2 The following sketch indicates the path of the jar during the agitation period.

Note 3 – The jar itself does not turn on its vertical axis. The jar's vertical axis describes a circle with a 6 inch radius, as near as possible. Side F always faces the operator.

4.6 Continue the agitation at the rate of three complete rotations per second for one minute.

4.7 At the end of the agitation period, empty the contents of the jar over the nested No.8 or No. 10 and the No. 200 sieves.

4.8 Use the syringe or spray attachment and carefully wash out the jar, catching the wash water in the nested sieves, applying sufficient manipulation with the spatula to expose entrapped fines, until the graduate is filled to 500 ml mark.

4.9 Remove the funnel and the nested sieves from the graduate. Bring all solids in the wash water into suspension by capping the graduate with the palm of the hand and turning the cylinder upside down and right side up ten times, through 180 degrees, as rapidly as possible.

4.10 Pour the thoroughly mixed liquid into the sand equivalent cylinder until the 15-inch mark is reached.

4.11 Place the stopper in the end of the cylinder, and mix the contents immediately. Mix the contents by alternately turning the cylinder upside down and right side up, allowing the bubble to completely traverse the length of the cylinder. Repeat this cycle 10 times in approximately 35 seconds. A complete cycle is from right side up to upside down to right side up.

4.12 At the completion of the mixing process, place the cylinder on the work table and remove the stopper. Allow the cylinder to stand undisturbed for 20 minutes. Immediately read and record to the nearest 0.1-inch, the height of the column of sediment.

4 Test Procedure: (continued)

Note 4 - There are two unusual conditions that may be encountered in this phase of the test procedure: A clearly defined line of demarcation may not form between the sediment and the liquid above it in the specified 20-minute period. If this happens, and the test is being made with the distilled or de-mineralized water, allow the cylinder to stand undisturbed until the clear demarcation line does form, then immediately read and record. If this should occur in a test being made with tap water, discontinue the test and re-test with distilled or de-mineralized water.

or, the liquid immediately above the line of demarcation may be still darkly clouded at the end of the 20-minute period, and the demarcation line, although distinct, may appear to be in the sediment column itself. If this should occur in a test being made with tap water, discontinue the test and re-test with distilled or de-mineralized water; otherwise, read and record this line of demarcation at the end of the specified 20-minute sedimentation period as usual.

5 Calculations:

5.1 Compute the cleanness value to the nearest whole number by the following formula:

$$CV = \frac{3.214 - (0.214H)}{3.214 - (0.786H)} x100$$

where: CV = Cleanness Value
H = Height of Sediment in Inches.

Solutions of the above equation are given in the table below:

Reading	CV	Reading	CV	Reading	CV	Reading	CV	Reading	CV
0.0	100	3.0	46	6.0	24	9.0	13	12.0	5
0.1	97	3.1	45	6.1	24	9.1	12	12.1	5
0.2	94	3.2	44	6.2	23	9.2	12	12.2	5
0.3	91	3.3	43	6.3	23	9.3	12	12.3	5
0.4	89	3.4	42	6.4	22	9.4	11	12.4	4
0.5	86	3.5	41	6.5	22	9.5	11	12.5	4
0.6	84	3.6	40	6.6	21	9.6	11	12.6	4
0.7	81	3.7	40	6.7	21	9.7	11	12.7	4
0.8	79	3.8	39	6.8	21	9.8	10	12.8	4
0.9	77	3.9	38	6.9	20	9.9	10	12.9	3
1.0	75	4.0	37	7.0	20	10.0	10	13.0	3
1.1	73	4.1	36	7.1	19	10.1	9	13.1	3
1.2	71	4.2	36	7.2	19	10.2	9	13.2	3
1.3	69	4.3	35	7.3	18	10.3	9	13.3	3
1.4	68	4.4	34	7.4	18	10.4	9	13.4	3
1.5	66	4.5	33	7.5	18	10.5	8	13.5	2
1.6	64	4.6	33	7.6	17	10.6	8	13.6	2
1.7	63	4.7	32	7.7	17	10.7	8	13.7	2
1.8	61	4.8	32	7.8	17	10.8	81	3.8	2
1.9	60	4.9	31	7.9	16	10.9	7	13.9	2
2.0	58	5.0	30	8.0	16	11.0	7	14.0	2
2.1	57	5.1	29	8.1	15	11.1	7	14.1	1
2.2	56	5.2	29	8.2	15	11.2	7	14.2	1
2.3	54	5.3	28	8.3	15	11.3	7	14.3	1
2.4	53	5.4	28	8.4	14	11.4	6	14.4	1
2.5	52	5.5	27	8.5	14	11.5	6	14.5	1
2.6	51	5.6	26	8.6	14	11.6	6	14.6	1
2.7	49	5.7	26	8.7	13	11.7	6	14.7	0
2.8	48	5.8	25	8.8	13	11.8	6	14.8	0
2.9	47	5.9	25	8.9	13	11.9	5	14.9	0
								15.0	0

6 Precautions:

6.1 Do not add too much water at the start of the test, Section 4.4. Only 500 ml total is allowed after final rinsing, Section 4.8.

7 Mechanical Agitation Method:

7.1 Alternate method for use with a Ro-Tap only:

7.1.1 Additional apparatus required:

Plastic container – 7 ½ in. diameter by 6 in. high.

Ro-Tap shaker.

8 Alternate Test Procedure:

8.1 Place the prepared aggregate sample in the plastic container. Add only enough water to completely cover the aggregate and secure the container in the Ro-Tap shaker.

8.2 Begin agitation after one minute has elapsed from the time of introduction of the wash water. Agitate the container for two minutes without the aid of the Ro-Tap hammer.

8.3 Immediately following the two minute agitation period, remove the container from the Ro-Tap shaker and remove the lid. Now agitate the contents by moving the upright container vigorously in a horizontal, circular motion five to six times in order to bring the fines into suspension. Immediately pour all of the contents in the nested No. 8 or No. 10 and No. 200 sieves placed in the 500 ml graduate.

8.4 Proceed with the test as outlined under the hand method beginning with Section 4.8.

8.5 Calculate the results according to Section 5.

9 Report:

9.1 Report all test results on Lab Form 123.

METHOD OF SAMPLING AND TESTING
MT 229-04
PROCEDURE FOR SOLIDS - WATER - VOIDS RELATIONS OF SOIL MASSES
(Zero-Air Voids)

1 Scope:

1.1 This method covers the compaction of soils by using the solids-water-voids (zero-air voids) chart. This method usually applies to the north central, eastern and southeastern areas of Montana but may apply to other areas of the state. It will be the responsibility of the District Materials Supervisor to monitor the applicability of this method.

2 Referenced Documents:

2.1 *AASHTO:*
T 100 Specific Gravity of Soils

2.2 *MT Materials Manual:*
MT-210 Moisture Density Relations of Soils Using a 5.5 Lb. Rammer and a 12 Inch Drop
MT-220 Specific Gravity of Soils
MT-230 Moisture Density Relations of Soils Using a 10 Lb. Rammer and a 18 Inch Drop

3 Procedure:

3.1 Air voids are another method used to determine the compaction of soils. The zero-air voids method will usually apply to soils classified from A-4 to A-7. When the zero-air voids method is not applicable, the 95% of maximum density and ±2% of optimum moisture will be used.

3.2 In order for this method to be accurate, it is necessary to find the specific gravity for the soils proposed for use. The most logical time to determine the specific gravity is during the pre-construction soil survey. However, due to the excavation process, which may result in a mixture of various soil strata, it may become necessary to perform additional specific gravity tests once the project is under contract. The specific gravity of soils is determined in accordance with MT-220, (AASHTO Designation T 100). (An average specific gravity is determined for the soil samples secured within any individual project.)

3.3 Individual proctor tests determined during the pre-construction soil survey are plotted on the zero-air voids chart. If the plot of the peaks from the family of proctor curves from the preliminary soil survey falls on a line roughly parallel to the zero-air voids, the zero-air voids method should work. Tests that fall to the left of the 10% air voids line are generally single size granular particle soils or excessively wet condition type soils. With these soils, the 95% of maximum density and ±2% of optimum moisture will be used.

3.5 Tests taken in the field that lie outside, or to the right of the 0% air voids line, not within the band, should be reviewed and treated as a failing test or possibly a bad reading by the density gauge. However, it is unusual to get tests that fall to the right of the 0% line. If tests consistently fall to the right of the 0% line, a specific gravity on the soil in question should be determined in accordance with MT-220, (AASHTO T100). Special Provision covers Proctor tests that plot outside the zero-air voids chart under compaction control. All proctor tests must be plotted on a zero-air voids chart to see if each test fits the zero-air voids chart.

4 Calculations:

4.1 Formula for calculating % voids:

$$\textbf{\% Voids = 100 -} \left(\left[\frac{d\left(1+\left[Gs\left(m/100\right)\right]\right)}{\left(Gs\right)\left(W\right)} \right] x100 \right)$$

Where:

US Standard

d = Dry Density in lb/ft³

Gs = Specific Gravity

m = % moisture

W = wt of water in lb/ft³ or 62. 42796

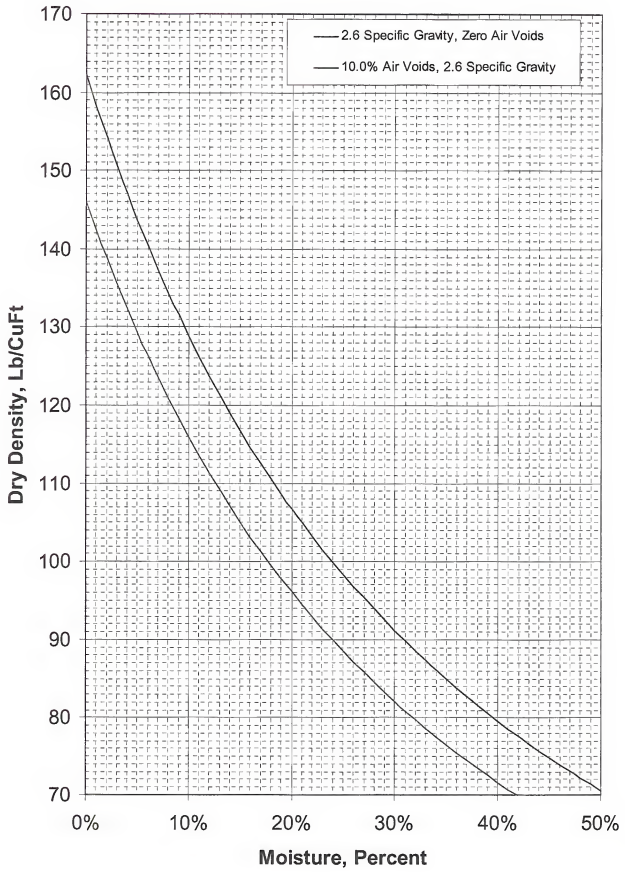
Metric

d = Dry Density in Kg/m³

Gs = Specific Gravity

m = % moisture

W = wt of water in Kg/m³ or 1000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10.0% Air Voids, 2.6 Specific Gravity
Dry Density, Lb/CuFt
170
160
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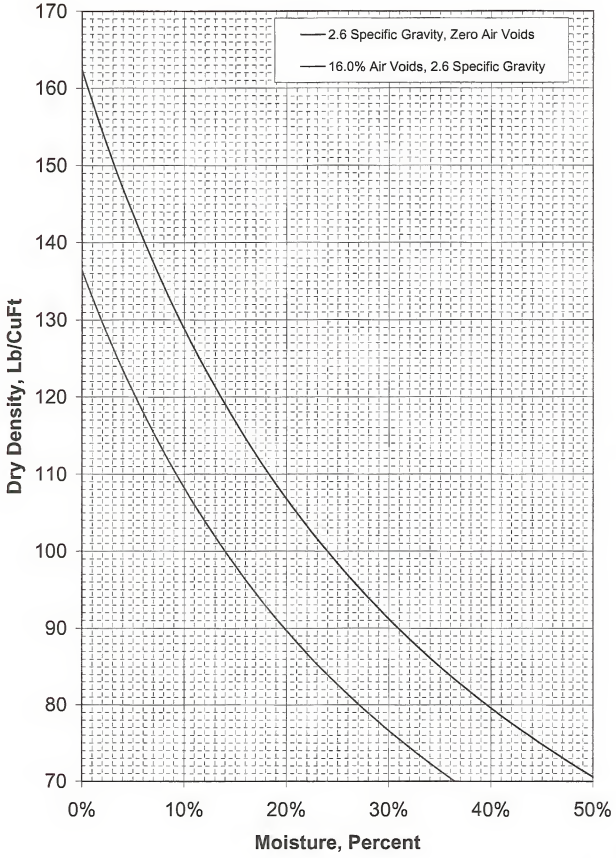
80
70
0%
10%
20%
30%
40%
50%
Moisture, Percent


2.6 Specific Gravity, Zero Air Voids
16.0% Air Voids, 2.6 Specific Gravity
Dry Density, Lb/CuFt
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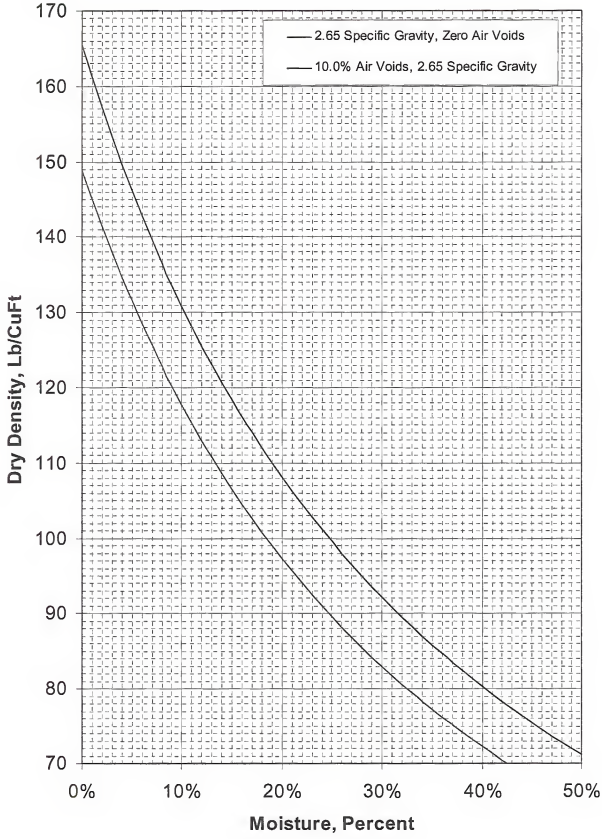
20%
30%
40%
50%
Moisture, Percent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Dry Density, Lb/CuFt
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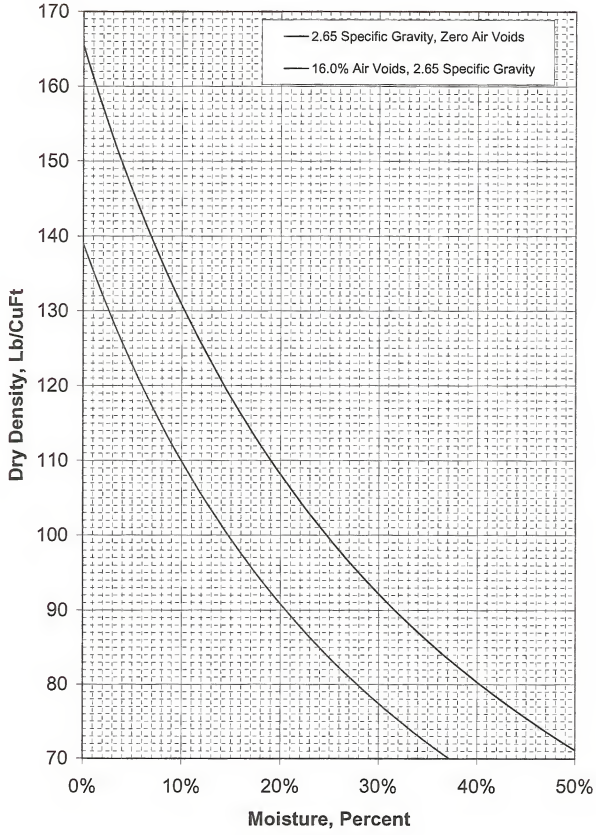
10%
20%
30%
40%
50%
Moisture, Percent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100
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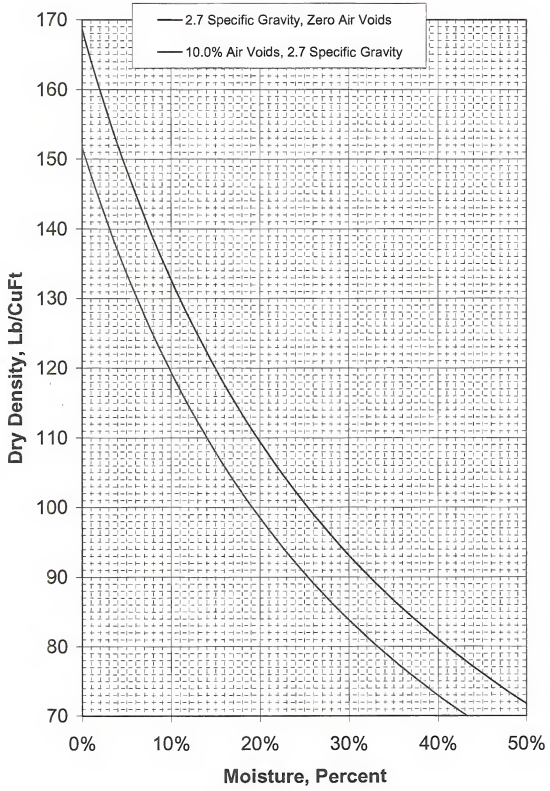
0%
10%
20%
30%
40%
50%
Moisture, Percent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Dry Density, Lb/CuFt
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80
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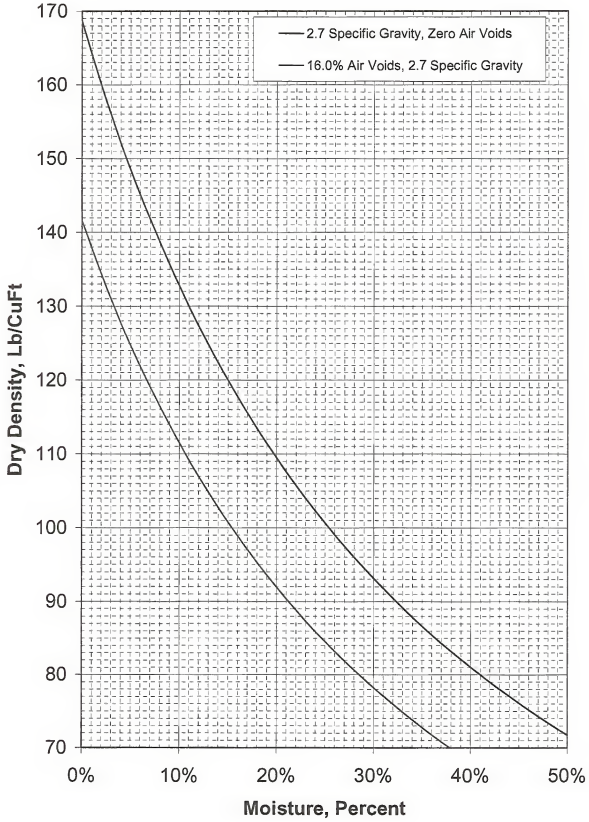
20%
30%
40%
50%
Moisture, Percent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16.0% Air Voids, 2.7 Specific Gravity
Dry Density, Lb/CuFt
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120
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100
90
80
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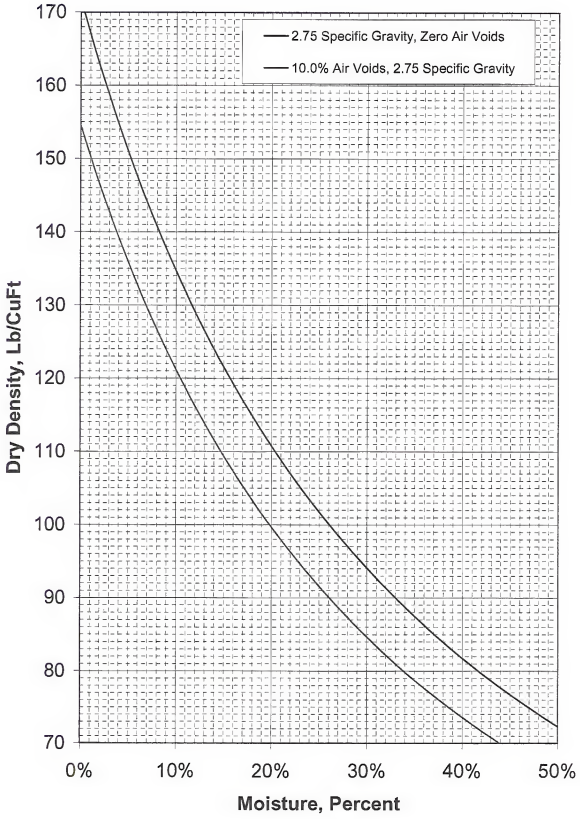
0%
10%
20%
30%
40%
50%
Moisture, Percent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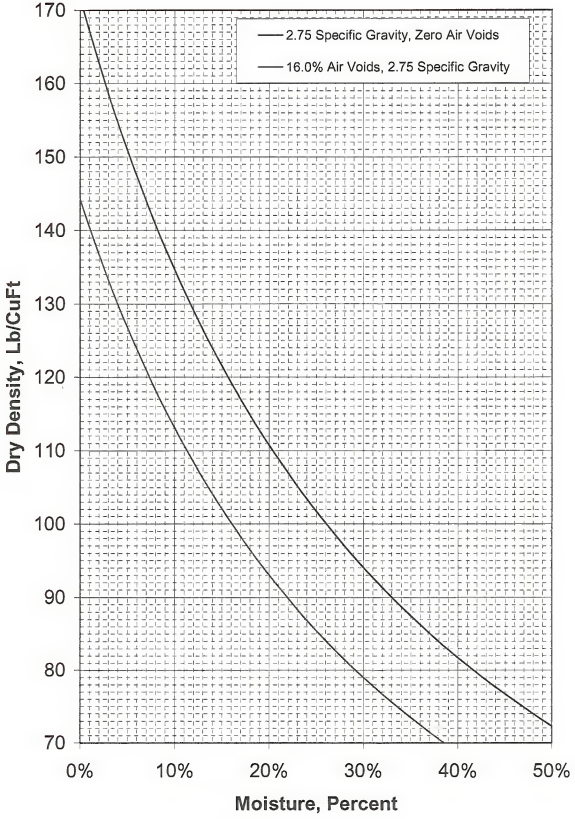
Moisture, Percent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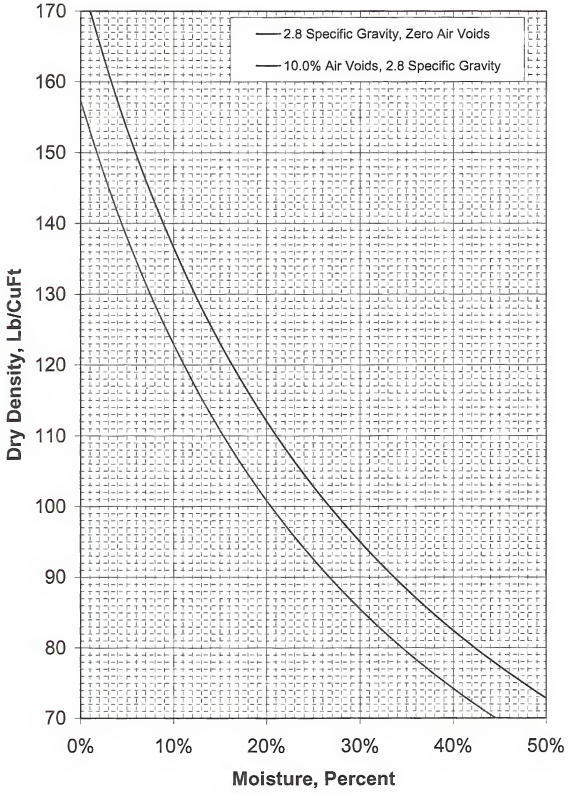
20%
30%
40%
50%
Moisture, Percent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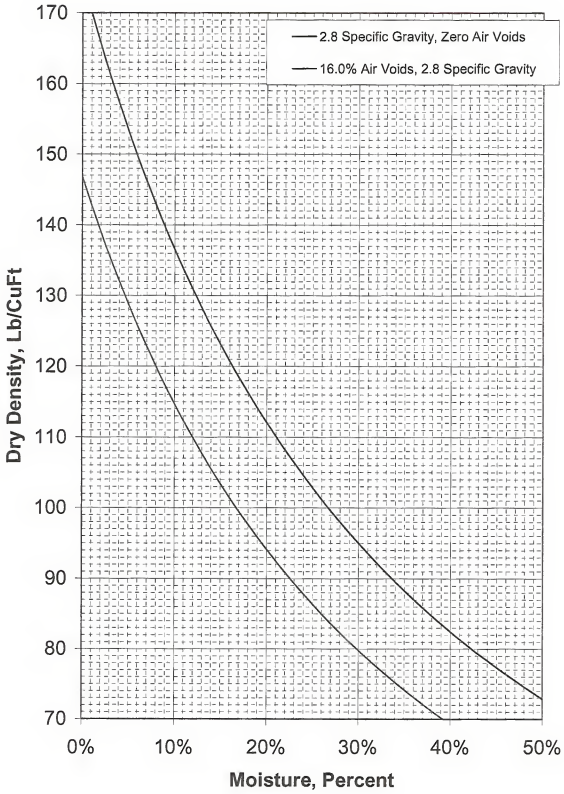
40%
50%
Moisture, Percent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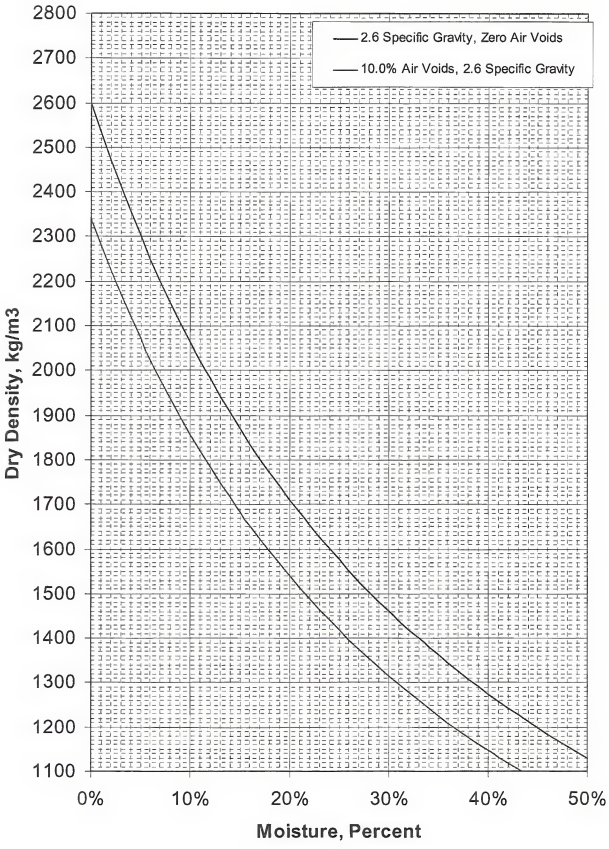
50%
Moisture, Percent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2300
2200
2100
2000
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1800
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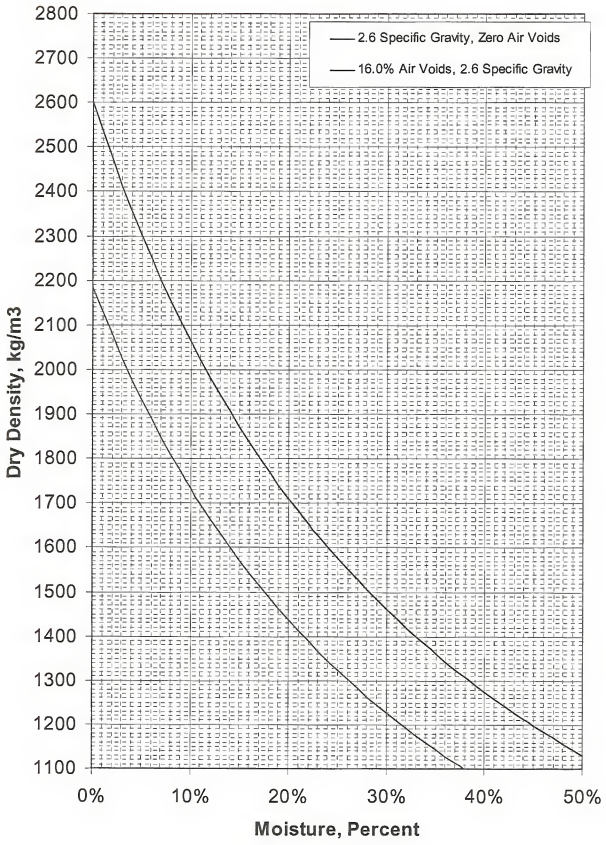
1100
0%
10%
20%
30%
40%
50%
Moisture, Percent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2200
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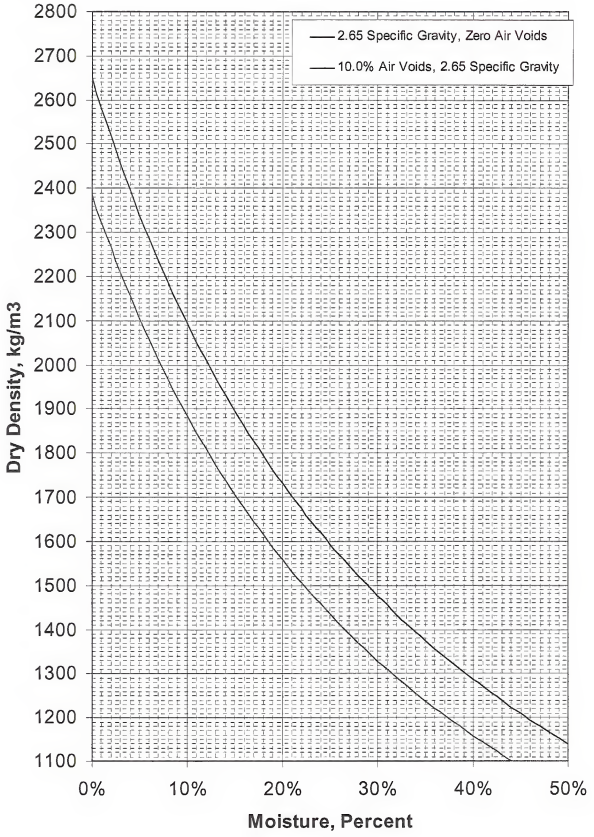
40%
50%
Moisture, Percent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Dry Density, kg/m3
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2600
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1100
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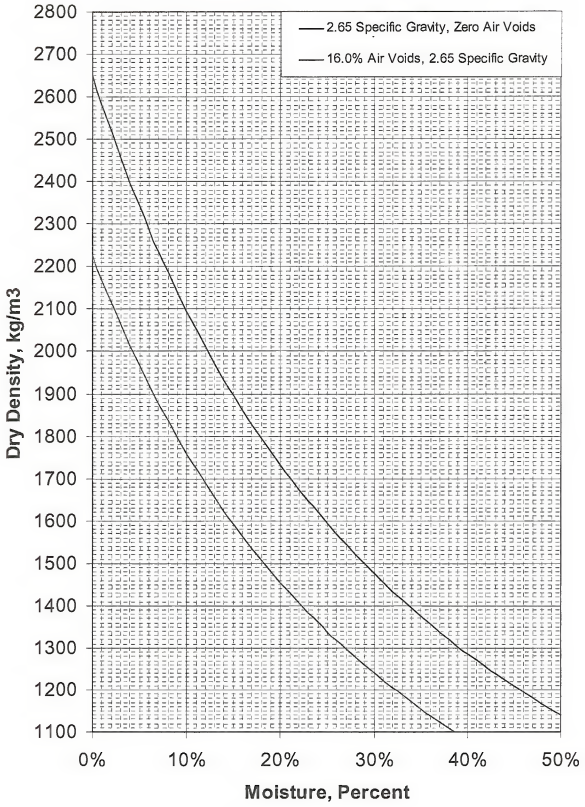
40%
50%
Moisture, Percent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16.0% Air Voids, 2.65 Specific Gravity
Dry Density, kg/m3
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2700
2600
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2200
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2000
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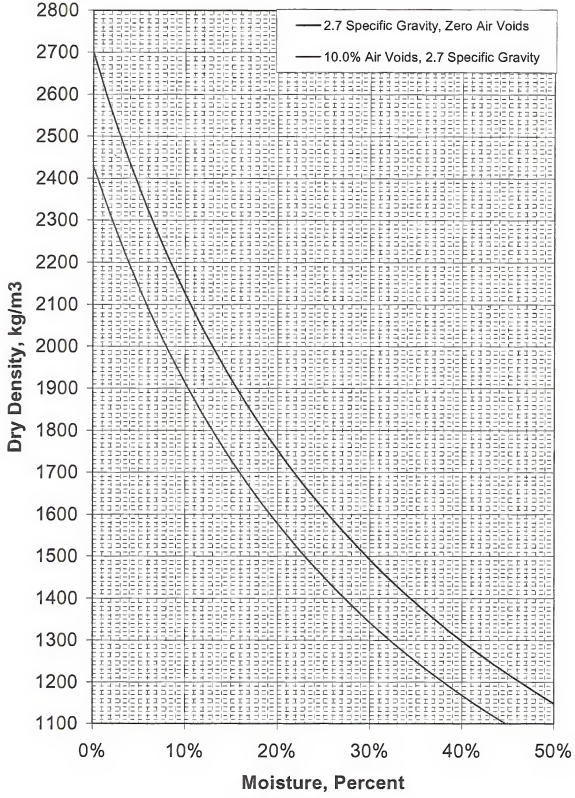
1300
1200
1100
0%
10%
20%
30%
40%
50%
Moisture, Percent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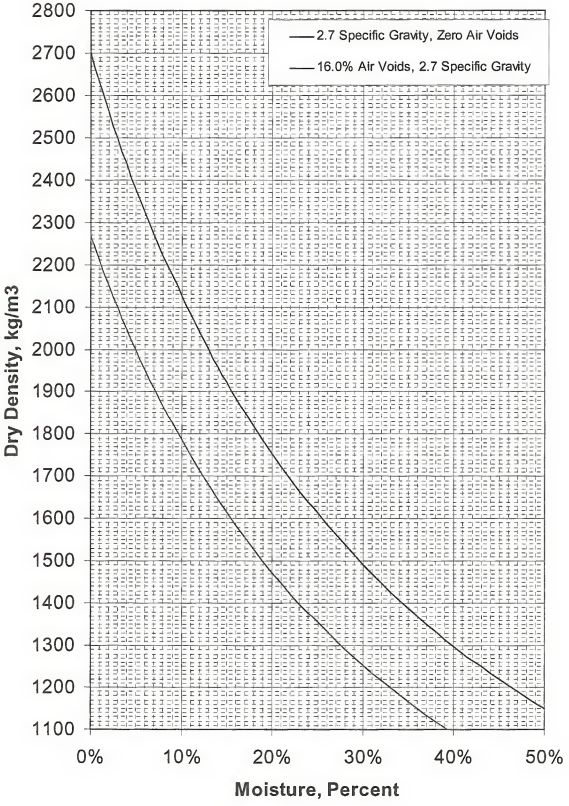
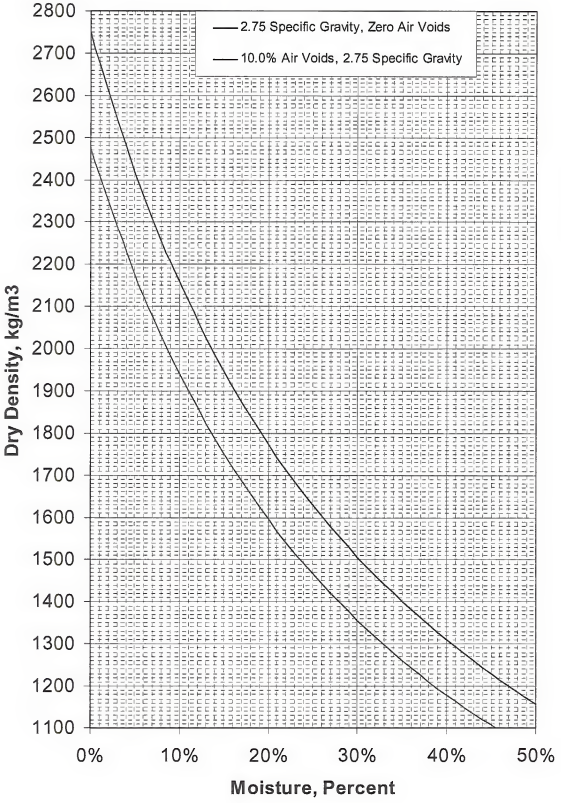
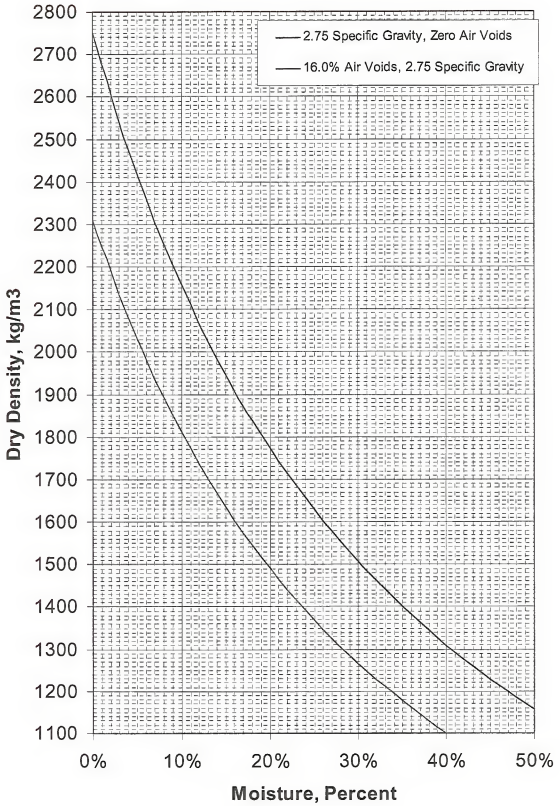
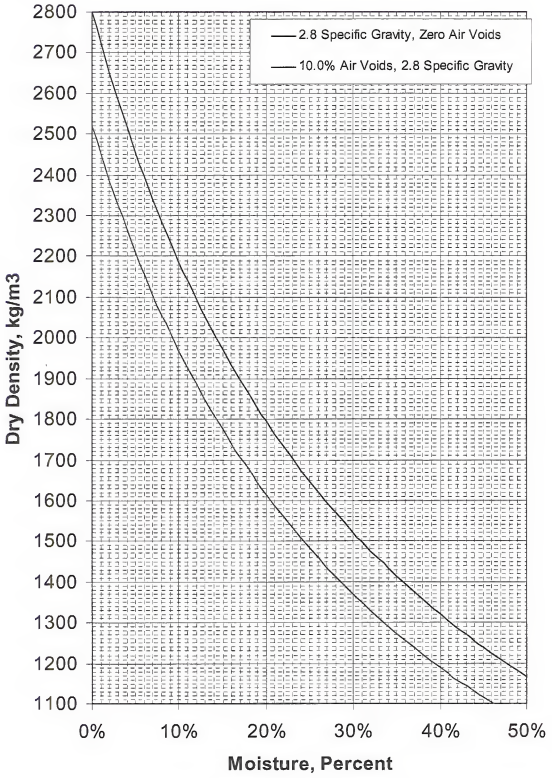
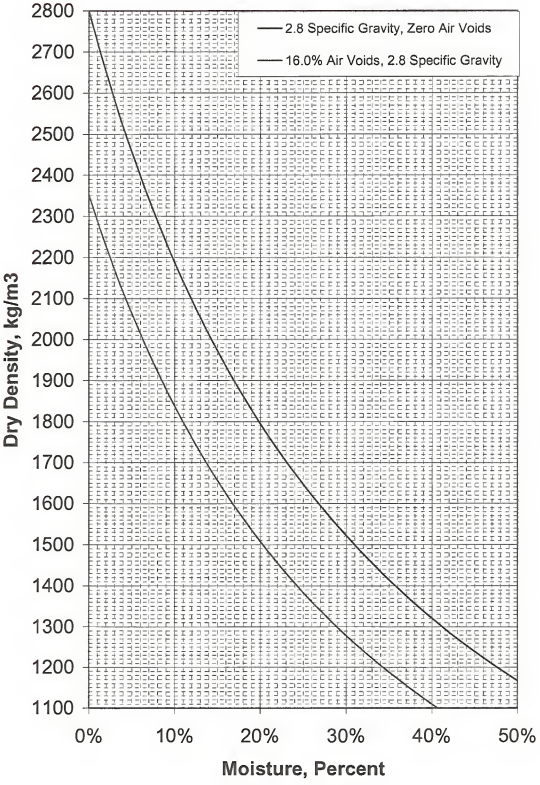
10.0% Air Voids, 2.7 Specific Gravity
Dry Density, kg/m3
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
0%
10%
20%
30%
40%
50%
Moisture, Percent


2.7 Specific Gravity, Zero Air Voids
16.0% Air Voids, 2.7 Specific Gravity
Dry Density, kg/m3
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
0%
10%
20%
30%
40%
50%
Moisture, Percent


2.75 Specific Gravity, Zero Air Voids
10.0% Air Voids, 2.75 Specific Gravity
Dry Density, kg/m3
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
0%
10%
20%
30%
40%
50%
Moisture, Percent


2.75 Specific Gravity, Zero Air Voids
16.0% Air Voids, 2.75 Specific Gravity
Dry Density, kg/m3
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
0%
10%
20%
30%
40%
50%
Moisture, Percent


2.8 Specific Gravity, Zero Air Voids
10.0% Air Voids, 2.8 Specific Gravity
Dry Density, kg/m3
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
0%
10%
20%
30%
40%
50%
Moisture, Percent


2.8 Specific Gravity, Zero Air Voids
16.0% Air Voids, 2.8 Specific Gravity
Dry Density, kg/m3
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
0%
10%
20%
30%
40%
50%
Moisture, Percent

METHODS OF SAMPLING AND TESTING
MT 230-04
METHOD OF TEST FOR THE MOISTURE-DENSITY RELATIONS OF SOILS USING A 10 LB. (4.54 KG) RAMMER AND A 18 IN. (457 MM) DROP
(Modified AASHTO T180)

1 Scope:

1.1 These methods of test are intended for determining the relation between the moisture content and density of soils compacted in a mold of a given size with a 10 lb. (4.54 kg) rammer dropped from a height of 18 in. (457 mm). Four alternate procedures are provided as follows:
Method A--A 4 in. (101.60 mm) mold: soil material passing a 4.75 mm (No. 4) sieve Sections 3 and 4.
Method B--A 6 in. (152.40 mm) mold: soil material passing a 4.75 mm (No. 4) sieve Sections 5 and 6.
Method C--A 4 in. (101.60 mm) mold: soil material passing a 19.0 mm (¾ in.) sieve Sections 7 and 8.
Method D--A 6 in. (152.40 mm) mold: soil material passing a 19.0 mm (¾ in.) sieve Sections 9 and 10.

1.2 The method to be used should be indicated in the specifications for the material being tested. If no method is specified, the provisions of Method A shall govern.

1.3 This test method applies to soil mixtures that have 40 percent or less retained on the 4.75 mm (No. 4) sieve, when Method A or B is used and 30 percent or less retained on the 19 mm (3/4 in.) sieve, when Method D or C is used. The material retained on these sieves shall be defined as oversize particles (coarse particles).

1.4 If the test specimen contains oversize particles, and the test specimen is used for field density compaction control, corrections must be made according to MT-231 to compare the total field density with the compacted specimen. The person or agency specifying this method shall specify a minimum percentage of oversize particles below which correction for oversize need not be applied. If no percentage is specified, correction shall be applied to samples with more than five percent by mass of oversize particles.

1.5 The following applies to all specified limits in this standard: For the purposes of determining conformance with these specifications, an observed value or a calculated value shall be rounded off "to the nearest unit" in the last right hand place of figures used I expressing the limiting value, in accordance with AASHTO R 11.

2 Referenced Documents:

3 Apparatus:

3.1 *Molds*--The molds shall be solid-wall, metal cylinders manufactured with dimensions and capacities shown in 2.1.1 and 2.1.2 below. They shall have a detachable collar assembly approximately 23/8-_ in. (60 mm) in height, to permit preparation of compacted specimens of soil-water mixtures of the desired height and volume. The mold and collar assembly shall be so constructed that it can be fastened firmly to a detachable base plate made of the same material (Note 1).

3 Apparatus: (continued)

Note 1 - Alternate types of molds with capacities as stipulated herein may be used, provided the test results are correlated with those of the solid-wall mold on several soil types and the same moisture-density results are obtained. Records of such correlation shall be maintained and readily available for inspection, when alternate types of molds are used.

2.1.1 A 4 in. Mold having a capacity of 1/30 (0.0333) ± 0.0003 cu. ft. (0.000943 ± 0.000008 m^3) with an internal diameter of 4.000 ± 0.016 in. (101.6 ± 0.41 mm) and a height of 4.584 ± 0.005 in. (116.43 ± 0.13 mm).

2.1.2 A 6 in. Mold having a capacity of 1/13.33 (0.07500 ± 0.00075 cu. ft. (0.002124 ± 0.000021 m^3) with an internal diameter of 6.000 ± 0.026 in. (152.40 ± 0.66 mm) and a height of 4.584 ± 0.005 in. (116.43 ± 0.13 mm).

2.1.3 *Molds Out of Tolerance Due to Use*--A mold that fails to meet manufacturing tolerances after continued service may remain in use provided those tolerances are not exceeded by more than 50 percent; and the volume of the mold, calibrated in accordance with par 4 (Calibration of Measure) of MT-203, for Unit Weight of Aggregate, is used in the calculations.

2.2 ***Rammer:***

2.2.1 *Manually Operated*--Metal rammer having a flat circular face of 2.000 ± 0.01 in. (50.80 ± 0.25 mm) diameter, a wear tolerance of 0.01 in. (.025 mm) and weighing 10.00 ± 0.02 lb, (4.536 ± 0.009 kg). The rammer shall be equipped with a suitable guide-sleeve to control the height of drop to a free fall of 18.00 ± 0.06 (or 1/16) in. (457 ± 2mm) above the elevation of the soil. The guide-sleeve shall have at least 4 vent holes, no smaller than 3/8 in. (9.5 mm) diameter spaced approximately 90 deg. (1.57 rad) apart and approximately ¾ in. (19 mm) from each end; and shall provide sufficient clearance so the free fall of the rammer shaft and head is unrestricted.

2.2.2 *Mechanically Operated*--A metal rammer which is equipped with a device to control the height of drop to a free fall of 18.00 ± 0.06 (or 1/16) in. (457 ± 2 mm) above the elevation of the soil and uniformly distributes such drops to the soil surface. The rammer shall have a flat circular face 2.000 ± 0.01 in. (50.80 ± 0.25 mm) diameter, a wear tolerance of 0.01 in. (0.25 mm) and a manufactured mass of 10.00 ± 0.02 lb. (4.536 ± 0.009 kg) (Note 2). The mechanical rammer shall be calibrated, by ASTM Method D 2168, to give the same moisture-density results as with a manually operated rammer.

Note 2 - It may be impractical to adjust the mechanical apparatus so the free fall is 18 in. (457 mm) each time the rammer is dropped, as with the manually operated rammer. To make the adjustment of free fall, the portion of loose soil to receive the initial blow should be slightly compressed with the rammer to establish the point of impact from which the 18 in. (457 mm) drop is determined. Subsequent blows on the layer of soil being compacted may all be applied by dropping the rammer from a height of 18 in.

2.2.3 *Rammer Face*--The circular face rammer shall be used but a sector face may be used as an alternative provided the report shall indicate type of face used other than the 2 in. (50.8 mm) circular face and it shall have an area equal to that of the circular face rammer.

2.3 *Sample Extruder*--A jack, lever, frame, or other device adopted for the purpose of extruding compacted specimens from the mold.

2.4 *Balances and Scales*--A balance or scale of at least 25 lb. capacity having a sensitivity and readability to 0.01 lb., or a balance or scale having a capacity of approximately 11.5 kg and a sensitivity and readability to 5 grams. (Note 3) Also, a balance of at least 1 kg capacity with a sensitivity and readability to 0.1 g.

2 Apparatus: (continued)

Note 3 - The capacity of the metric balance or scale should be approximately 11.5 kg when used to weigh the 6 in. (152 mm) mold and compacted, moist soil; however, when the 4-in. (102 mm) mold is used, a balance or scale of lesser capacity than the 11.5 kg may be used, if the sensitivity and readability is 5 g.

2.5 *Drying Oven*--A thermostatically controlled drying oven capable of maintaining a temperature of 110 ± 5°C (230 ± 9°F) for drying moisture samples.

2.6 *Straightedge*--A hardened-steel straightedge at least 10 in. (250 mm) in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.01 in. per 10 in. (0.1 percent) of length within the portion used for trimming the soil (Note 4).

Note 4 - The beveled edge may be used for final trimming if the edge is true within a tolerance of 0.25 mm per 250 mm (0.001 in. per 10 in.) (0.1 percent) of length; however, with continued use, the cutting edge may become excessively worn and not suitable for trimming the soil to the level of the mold. The straightedge should not be so flexible that trimming the soil with the cutting edge will cause a concave soil surface.

2.7 *Sieve*-- 2-in. (50 mm), ¾-in. (19.0 mm), and No. 4 (4.75 mm) sieves conforming to the requirements of MT-405, (AASHTO M 92), Sieves for Testing Purposes.

2.8 *Mixing Tools*--Miscellaneous tools such as mixing pan, spoon trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

2.9 *Containers*--Suitable containers made of material resistant to corrosion and not subject to change in weight or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial weighing and to prevent absorption of moisture from the atmosphere following drying and before final weighing. One container is needed for each moisture content determination.

METHOD A

3 Sample:

3.1 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of drying apparatus such that the temperature of the sample does not exceed 60 C (140 F). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.

3.2 Sieve an adequate quantity of the representative pulverized soil over the No. 4, (4.75 mm) sieve. Discard the coarse material, if any, retained on the No. 4, (4.75 mm) sieve.

3.3 Select a representative sample, with a mass of approximately 7 lb. (3 kg) or more, of the soil prepared as described in Sections 3.1 and 3.2.

4 Procedure:

4.1 Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately four percentage points below optimum moisture content.

4.2 Form a specimen by compacting the prepared soil in the 4 in. (101.60 mm) mold (with collar attached) in five approximately equal layers to give a total compacted depth of about 5 in. (125 mm). Prior to compaction, place the loose soil into the mold and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose or fluffy state, using either the manual compaction rammer or a similar device having a face diameter of approximately 2 inches (50 mm). Compact each layer by 25 uniformly distributed blows from the rammer

4 Procedure: (continued)

dropping free from a height of 18 in. (457 mm) above the elevation of the soil when a sleeve-type rammer is used, or from 18 in. (457 mm) above the approximate elevation of compacted soil when a stationary mounted type of rammer is used. During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation (Note 5).

Note 5 - Each of the following has been found to be a satisfactory base on which to rest the mold during compaction of the soil: A block of concrete, weighing not less than 200 lb. (90 kg), supported by a relatively stable foundation; a sound concrete floor; and for field application, such surfaces as found in concrete box culverts, bridges, and pavements.

4.2.1 Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge, and weigh the mold and moist soil in pounds, to the nearest 0.01 lb., or weigh in kilograms to the nearest 5 grams. For molds conforming to tolerances given in Section 2.1.1 and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 30, and record the result as the wet density, W_1, in pounds per cubic foot, of compacted soil. For molds conforming to tolerances given in Section 2.1.1 and masses recorded in kilograms, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 1060, and record the result as the wet density, W_1, in kilograms per cubic meter, of compacted soil. For used molds out of tolerance by not more than 50 percent (2.1.3), use the factor for the molds as determined in accordance with Section 6 (Calibration of Measure), MT-203.

4.3 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material from one of the cut faces, weigh immediately, and dry in an oven at 110 ± 5°C (230 ± 9°F) for at least 12 hours, or to a constant mass to determine the moisture content. The moisture sample shall weigh not less than 100 g.

4.4 Thoroughly break up the remaining portion of the molded specimen until it will pass a No. 4, (4.75 mm) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amount to increase the moisture content of the soil by one or two percentage points, and repeat the above procedure for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet unit mass. W_1, per cubic foot or cubic meter of the compacted soil (Note 6).

Note 6 - This procedure has been found satisfactory in most cases. However, in instances where the soil material is fragile in character and will reduce significantly in grain size due to repeated compaction, and in cases where the soil is a heavy-textured clayey material into which it is difficult to incorporate water, a separate and new sample shall be used in each compaction test. In these cases, separate samples shall be thoroughly mixed with amounts of water sufficient to cause the moisture contents of the samples to vary by approximately two percentage points. The moisture points selected shall bracket the optimum moisture content, thus providing samples which when compacted will increase in mass to the maximum density and then decrease in mass. The samples of soil-water mixtures shall be placed in covered containers and allowed to stand for not less than 12 h before making the moisture-density test.

4.4.1 In instances where the soil material is fragile in character and will be reduced significantly in grain size by repeated compaction, a separate and new sample shall be used in each compaction test.

METHOD B

5 Sample:

5.1 Select the representative sample in accordance with 3.3, except that it shall have a mass of approximately 16 lb. (7 kg).

6 Procedure:

6.1 Follow the same procedure as described for Method A in Section 4, except for the following: Form a specimen by compacting the prepared soil in the 6-in. (152.40 mm) mold (with collar attached) in five approximately equal layers to give a total compacted depth of about 5 in. (125 mm), each layer being compacted by 56 uniformly distributed blows from the rammer. For molds conforming to tolerances in 2.1.2, and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 13.33, and record the result as the wet density, W_t, in lb. ft.^{3}, of the compacted soil. For molds conforming to tolerances given in 2.1.2 and masses recorded in kilograms, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 471, and record the results as the wet density, W_t, in kg/m^3, of compacted soil. For used molds out of tolerance by not more than 50 percent (2.1.3), use the factor for the mold as determined in accordance with Section 6 (Calibration of Measure), MT-203.

METHOD C

7 Sample:

7.1 If the soil sample is damp when received from the field, dry it until it becomes friable under a trowel. Drying may be in air or by use of drying apparatus such that the temperature does not exceed 60 C (140°F). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.

7.2 Sieve an adequate quantity of the representative pulverized soil over the ¾-in., (19.0 mm) sieve. Discard the coarse material if any, retained on the ¾-in., (19.0 mm) sieve (Note 7).

Note 7 - If it is advisable to maintain the same percentage of coarse material (passing a 2-in., (50 mm) sieve and retained on a No. 4, (4.75 mm) sieve) in the moisture-density sample as in the original field sample, the material retained on the ¾-in., (19.0 mm) sieve shall be replaced as follows: Sieve an adequate quantity of the representative pulverized soil over the 2-in., (50 mm) and ¾-in., (19.0 mm) sieve. Weigh the material passing the 2-in., (50 mm) sieve and retained on the ¾-in., (19.0 mm) sieve and replace it with an equal mass of material passing the ¾-in., (19.0 mm) sieve and retained on the No. 4, (4.75 mm) sieve. Take the material for replacement from the remaining portion of the sample.

7.3 Select a representative sample, having a mass of approximately 12 lb. (5 kg) or more, of the soil prepared as described in 7.1 and 7.2.

8 Procedure:

8.1 Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately 4 percentage points below optimum moisture content.

8.2 Form a specimen by compacting the prepared soil in the 4 in. (101.60 mm) mold (with collar attached) in five approximately equal layers to give a total compacted depth of about 5 in. (125 mm). Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 18 in. (457 mm) above the elevation of the soil when a sleeve-type rammer is used, or from 18 in. (457 mm) above the approximate elevation of each finally compacted layer when a stationary mounted type rammer is used. During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation (Note 5).

8.2.1 Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge. Holes developed in the surface by removal of coarse material shall be patched with smaller size material. Weigh the mold and moist soil in pounds to the nearest 0.01 lb.; or weigh in kilograms to the nearest 5 grams. For molds conforming to tolerances given in Section 2.1.1, and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 30, and record

8 Procedure: (continued)

the result as the wet density, W_1, in lb./ft.^{3}, of compacted soil. For molds conforming to tolerances given in Section 2.1.1 and masses recorded in kilograms, multiply the mass of the compacted specimen and mold, minus the mass of the mold, by 1060, and record the result as wet density, W_1, in kg/m^3, of compacted soil. For used molds out of tolerance by not more than 50 percent (2.1.3), use the factor for the mold as determined in accordance with Section 6 (Calibration of Measure), MT-203.

8.3 Remove the material from the mold and slice vertically through the center. Take a representative sample of the material from one of the cut faces, weigh immediately, and dry in an oven at 110 ± 5 C (230 ± 9ºF) for at least 12 hours, or to constant mass, to determine the moisture content. The moisture content sample shall weigh not less than 500 g.

8.4 Thoroughly break up the remainder of the material until it will pass a ¾-in., (19.0 mm) sieve and 90 percent of the soil aggregations will pass a No. 4, (4.75 mm) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage points, and repeat the above procedure for each increment of water added. Continue this series of determinations until there is either a decrease or no change in the wet mass, W_1, per cubic foot or cubic meter of compacted soil (Note 6).

METHOD D

9 Sample:

9.1 Select the representative sample in accordance with 7.3 except that it shall have a mass of approximately 25 lb. (11 kg).

10 Procedure:

10.1 Follow the same procedure as described for Method C in section 8 except for the following. Form a specimen by compacting the prepared soil in the 6 in. (152.40 mm) mold (with collar attached) in five approximately equal layers to give a total compacted depth of about 5 in. (125 mm), each layer being compacted by 56 uniformly distributed blows from the rammer. For molds conforming to tolerances given in 2.1.2 and masses recorded in pounds, multiply the mass of the compacted specimen and the mold, minus the mass of the mold, by 13.33, and record the results as the wet unit mass, W_1, in lb/ft^3, of the compacted soil. For molds conforming to tolerances given in 2.1.2 and masses recorded in kilograms, multiply the mass of the compacted specimen and mold, minus the mass of the mold, by 471, and record the result as the wet unit mass, W_1, in kg/m^3 of compacted soil. For used molds out of tolerance by not more than 50 percent (2.1.3), use the factor for the mold as determined in accordance with Section 6 (Calibration of Measure) MT-203.

CALCULATIONS AND REPORT

11 Calculations:

11.1 Calculate the moisture content and the dry unit mass of the soil as compacted for each trial, as follows:

$$w = \frac{A - B}{B - C} \times 100$$

11 Calculations: (continued)

and

$$Pd = \frac{Pw}{w + 100} \times 100$$

where:

w = percentage of moisture in the specimen, based on oven dry mass of soil.

A = mass of container and wet soil.

B = mass of container and dry soil.

C = mass of container.

Pd = dry mass, in pounds per cubic foot of compacted soil, or kilograms per cubic meter of compacted soil, and

Pw = wet mass, in pounds, per cubic foot of compacted soil or kilograms per cubic meter of compacted soil.

12 Moisture-Density Relationship:

12.1 The calculation in 11.1 shall be made to determine the moisture content and corresponding oven-dry unit mass (density) in pounds per cubic foot or kilograms per cubic meter of the compacted samples. The oven-dry densities (unit weight) of the soil shall be plotted as ordinates and the corresponding moisture content as abscissas.

12.2 *Optimum Moisture Content*--When the densities and corresponding moisture contents for the soil have been determined and plotted as indicated in 12.1, it will be found that by connecting the plotted points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve shall be termed the "optimum moisture-content" of the soil under the above compaction.

12.1 The calculations in 11.1 shall be made to determine the moisture content and corresponding oven-dry unit mass (density) in pounds per cubic foot or kilograms per cubic meter of the compacted samples. The oven-dry densities (unit weight) of the soil shall be plotted as ordinates and the corresponding moisture content as abscissas.

12.2 *Optimum Moisture Content*--When the densities and corresponding moisture contents for the soil have been determined and plotted as indicated in 12.1, it will be found that by connecting the plotted points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve shall be termed the "optimum moisture-content" of the soil under the above compaction.

12.3 *Maximum Density*--The oven-dry density in pounds per cubic foot or kilograms per cubic meter of the soil at optimum moisture content shall be termed "maximum density" under the above compaction.

13 Report:

13.1 The report shall include the following:

13 Report: (continued)

13.1.1 The method used (Method A, B, C, or D)

13.1.2 The optimum moisture content, as a percentage, to the nearest whole number

13.1.3.1 The maximum density in lbs. per cu. ft., to the nearest 0.1 lb/ft^3 or in kilograms per cubic meter, to the nearest 1 kg.

13.1.3.2 In Methods C and D indicate if the material retained on the 19.0 mm sieve was removed or replaced.

13.1.5 Type of face if other than 2 in. (50.8 mm) circular.

METHOD OF SAMPLING AND TESTING
MT 231-04
PROCEDURE FOR CORRECTION FOR COARSE PARTICLES
IN THE SOIL COMPACTION TEST
(Modified AASHTO T 224)

1 Scope:

1.1 This method describes a procedure for adjusting the densities of soil and soil aggregate mixtures to compensate for differing percentages of coarse particles retained on either the 4.75-mm (No. 4) or 19.0-mm (3/4 in.) sieve. This is necessary to adjust either the field wet density to a dry density of the material passing theses sieves or the reverse, by adjusting the lab density to the field density when doing compaction control testing. Comparisons are made by comparing the field densities with the maximum dry density as determined by MT-210 (*AASHTO T 99*) or MT- 230 (*AASHTO T 180*).

1.2 Two methods are available for correction, either, lab to field or field to lab density. The method specified in Section 4.1 adjusts the compacted lab density to the field density. The method specified in Section 4.2 adjusts the field wet density to dry density of the fine fraction and compares its results with the compacted lab density.

1.3 This test method applies to soil mixtures that have 40 percent or less retained on the 4.75-mm (No. 4) sieve, when Method A or B of MT 210 (*AASHTO T 99*) or MT 230 (*AASHTO T 180*) is used, or mixtures that have 30 percent or less retained on the 19.0-mm (3/4 in.) sieve, when Method C or D of MT 210 (*AASHTO T 99*) or MT 230 (*AASHTO T 180*) is used. The material retained on these sieves shall be defined as oversize particles (coarse particles.

1.4 This method applies to soils with any percentage of oversize particles as specified in Section 1.3. However, the correction may not be of practical significance for soils with only a small percentage of oversize particles. The person or agency specifying this method shall specify a minimum percentage of oversize particles below which the method need not be applied. If a minimum percentage is not specified, this method shall be applied to samples with more than 5 percent by weight of oversize particles.

1.5 The following applies to all specified limits in this standard: For the purpose of determining conformance with these specifications, an observed value or a calculated value shall be rounded off to the nearest 10kg/m³ (1 pcf), according to R 11, Recommended Practice for Indicating Which Places of Figures Are to Be considered Significant in Specified Limiting Values.

1.6 The values in SI units are to be considered as the standard.

2 Reference Documents:

2.1 AASHTO Standards:

R 11 Recommended Practice for Indicating Which Places of Figures Are to Be Considered Significant in Specified Limiting Values
T 85 Specific Gravity and Absorption of Coarse Aggregate
T 99 The Moisture-Density Relations of Soils Using a 2.5-kg (5.5 –lb) Rammer and a 305-mm (12-in.) Drop
T 180, Moisture-Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in) Drop
T 217 Determination of Moisture in Soils by Means of a Calcium Carbide Gas Pressure Moisture Tester
T 255 Total Moisture Content of Aggregate by Drying
T 272 Family of Curves-One Point Method

3 Outline of Method:

3.1 When method A or B of MT-210 or MT-230 is employed, the total field wet density is compared with the dry density of the soil particles passing the 4.75-mm (No. 4) sieve.

3.2 When method C or D of MT-210 or MT-230 is employed, the total field wet density is compared with the dry density of the soil particles passing the 19.0-mm (3/4 in) sieve.

3.3 Significant figures are as follows:

3.3.1 Adjusted wet density of the fine material passing the 4.75-mm (No. 4) sieve, Methods A and B; or 19.0-mm (3/4 in.) sieve, Methods C and D: (D_f) 1 kg/m³ (0.1pcf).

3.3.2 Bulk specific gravity of the coarse material retained on the 4.75-mm (No. 4) sieve, Methods A and B; or 19-mm (3/4 in.) sieve, Methods C and D; (G_m) 0.01.

3.3.3 Percent by mass, of coarse and fine particles, of material retained and passing the 4.75-mm (No. 4) sieve, Methods A and B; or 19.0-mm (3/4 in.) sieve, Methods C and D; (P_c) and (P_f) 0.1 percent.

3.3.4 In-place (field) wet density of the total sample (D) 1 kg/m³ (0.1 pcf).

4 Adjustment Equation:

4.1 *Compacted Laboratory Dry Density Corrected to Field Dry Density*

4.1.1 This section corrects the laboratory density obtained by either MT-210 or MT-230 for the moisture content and density of the material retained on the 4.74-mm (No. 4) sieve, Methods A and B; or the material retained on the 19.0-mm (3/4 in.) sieve, Methods C and D. The maximum laboratory dry density, adjusted for oversized particles and total moisture content are compared with the field dry density and field moisture content. This method is limited to field samples containing 40 percent or less of material retained on the 4.75-mm (No. 4) sieve, Methods A and B, or 30 percent or less of material retained on the 19.0-mm (3/4 in.) sieve, Methods C and D.

4.1.2 Determine the moisture content of the fine particles and oversize particles of the material used during compaction. The moisture contents can be determined by T 265, T 217, or T 255. The moisture content of the oversize material retained on the sieve can be assumed to be two (2) percent for most construction applications. If the moisture content of the oversized material is generally known, substitute the moisture content in the calculations. If drying equipment is available, determine the actual moisture contents. Calculate the moisture contents according to the calculations specified in T 265.

4.1.3 Calculate the dry mass of the coarse and fine particles as follows:

$M_D = M_M/(1+MC)$

where:

M_D = mass of dry material (fine or oversize particles).

M_M = mass of moist material (fine or oversize particles).

MC = moisture content of respective fine or oversized particles, expressed as a decimal.

4 Adjustment Equation: (continued)

Calculate the percentage of the fine particles and oversized particles by dry weight of the total sample as follows:

$P_f = 100\, M_{DF}/(M_{DF} + M_{DC})$

and

$P_C = 100\, M_{DC}/(M_{DF} + M_{DC})$

where:

P_f = percent of fine particles, of sieve used, by weight.

P_C = percent of oversized particles, of sieve used, by weight.

M_{DF} = mass of dry particles and

M_{DC} = mass of oversize particles.

4.1.4 Calculate the corrected moisture content and corrected dry density of the total sample (combined fine and oversize particles) as follows:

$MC_T = (MC_f P_f + MC_C P_C)/100$

where:

MC_T = corrected moisture content of the combined fine and oversized particles, expressed as a decimal.

MC_f = moisture content of the fine particles, expressed as a decimal.

MC_C = moisture content of oversize particles, expressed as a decimal.

and

$D_d = 100\, D_f k/(D_f P_C + k P_f)$

where:

D_d = corrected total dry density (combined fine and oversize particles) kg/m³ (pcf).

D_f = dry density of the fine particles kg/m³ (pcf).

P_C = percent of oversize particles, of sieve used, by weight.

P_f = percent of fine particles, of sieve used, by weight.

K = 1,000 * Bulk Specific Gravity (G_m)(oven dry basis) of coarse particles (kg/m³),
Or 62.4*Bulk Specific Gravity(G_m)(oven dry basis) of coarse particles (pcf).

Note 1 – If the specific gravity has been determined, this value may be used in the calculations. Determine the Bulk Specific Gravity according to T 85. For most construction activities the specific gravity can be assumed to be 2.60.

4 Adjustment Equation: (continued)

4.2 Field Wet Density Corrected to Compacted Laboratory Density

4.2.1 The in-place total (field) wet density is corrected to a dry density of the sample passing the 4.75-mm (No. 4) sieve or the sample passing the 19.0-mm (3/4 in.) sieve. The adjusted dry density is compared with the maximum dry density obtained by methods T 99 or T 180.

4.2.2 Determine the moisture content of the total sample and for the material retained on the sieve used during compaction. Moisture content can be determined by either T 265, T 217 or T 255. If using the nuclear moisture/density gauge, read the moisture content directly from the gauge for the total moisture content. The moisture content of the oversize material retained on the sieve can be assumed to be two (2) percent for most construction applications. If the mosture content of the oversize material is generally known, substitute the moisture content in the calculations. IF drying equipment is available, determine the actual moisture contents. Calculate the moisture contents according to the calculations specified in T 265.

4.2.3 Calculate the moisture content of the fine particles of the field sample as follows:

$MC_f = (100MC_T - MC_cP_c)/P_f$

where:

MC_f = moisture content of the fine particles, expressed as a decimal.

MC_T = moisture content of total field sample, expressed as a decimal.

MC_c = moisture content of the oversize particles, expressed as a decimal.

P_c = percent of oversize particles, of sieve used, by weight.

P_f = percent of fine particles, of sieve used, by weight.

4.2.4 Calculate the dry field density of the sample as follows:

$D_d = D/(1+MC_T)$

where:

D_d = dry field density of total sample, kg/m³ (pcf).

D = total field wet density, kg/m³ (pcf).

MC_T = moisture content of total field sample, expressed as a decimal.

4.2.5 Calculate the dry field density of the fine particles of the field sample as follows:

$D_f = D_dP_f/(100-((D_dP_c)/k)))$

where:

D_f = adjusted dry density of the fine particles, kg/m³ (pcf).

D_d = total field dry density, kg/m³ (pcf).

4 **Adjustment Equation:** (continued)

P_f = percent of fine particles, of sieve used, by weight.

P_c = percent of oversize particles, of sieve used, by weight.

k = 1,000*Bulk Specific Gravity (G_M)(oven dry basis) of coarse particles (kg/m³), or 62.4* Bulk Specific Gravity (G_M)(oven dry basis) of coarse particles (pcf), (Note 1).

5 **Precision:**

5.1 Since this correction for coarse particles involves no testing but instead utilizes the results of other tests and mathematically combines the results, determination of the precision and accuracy is not applicable.

APPENDIX:

A1 NOTES:

A1.1 These methods, described for coarse particle correction, are applicable to one type of soil and soil-aggregate material only. If the characteristic of the material changes, then a moisture/density relationship (T 99 or T 180) test is performed to determine a new maximum density.

A1.2 T 272 describes the methods for determining different maximum densities of soil and soil-aggregate materials which reveal certain similarities and trends characteristic of the material type and source.

A1.3 *UTILIZATION OF A FAMILY OF CURVES* – When using the One Point Method (T 272), Note 3 does not apply. The percentage of oversize particles, when performing the density of soil and soil-aggregate in-place, must be determined to adjust the T 99 or T 180 maximum density to compensate for this percentage.

METHOD OF SAMPLING AND TESTING
MT 232-04
SOIL CORROSION TEST
(Montana Method)

1. Scope:

1.1 This test method covers procedures and apparatus for determining the pH, conductivity and sulfate content of a soil in corrosion testing.

1.2 The principle use of these tests is to supplement soil-resistivity measurements and thereby identify conditions under which the corrosion of metals in soil may be accentuated.

2. Apparatus:

2.1 *Sieves* – A series of sieves of the following sizes: 1/4 in. (6.3 mm), No. 4 (4.75 mm), No. 10 (2.00 mm) and a pan.

2.2 *Balance* – A balance readable to 0.1 percent of the sample mass, or better, and conforming to the requirements of AASHTO M 231.

2.3 *Drying Apparatus* – A suitable device capable of drying samples at a temperature of 140°F (60°C).

2.4 *Pulverizing Apparatus* – Either a mortar and a rubber-covered pestle or any device suitable for breaking up the aggregations of soil particles without reducing the size of the individual grains.

2.5 *Sample Splitter* – A suitable riffle sample splitter or sample splitter for proportional splitting of the sample and capable of obtaining representative portions of the sample without appreciable loss of fines. The width of the container used to feed the riffle splitter should be equal to the total combined width of the riffle chutes. Proportional splitting of the sample on a canvas cloth is also acceptable.

2.6 *pH Meter* – With electrodes suitable for laboratory analysis.

2.7 *Standard Buffer Solutions* – Buffer solutions with known pH values of 4.0, 7.0, 10.0.

2.8 *Beakers* – 100 ml and 250 ml wide mouth glass beakers with a watch glass for cover.

2.9 Glass stirring rods.

2.10 *Conductivity Meter* - Suitable for laboratory or field analysis.

2.11 *Muffle Furnace* – The muffle furnace shall be capable of operation at the temperatures required and shall have an indicating pyrometer accurate within ±25°C, as corrected, if necessary, by calibration.

2.12 *Platinum Crucible* – Platinum crucibles for ordinary chemical analysis should preferably be made of pure unalloyed platinum of 15 to 30-ml capacity. Where alloyed platinum is used for greater stiffness or to avoid sticking of crucible and lid, the alloyed platinum should not decrease in mass by more than 0.2 mg when heated at 1200°C for one hour.

2.13 *Filter Paper* – Fast filter paper (Whatman #41) and slow filter paper (Whatman #42).

3 Sample Preparation:

3.1 The sample as received shall be in a moist condition for pH purposes. If the sample is too wet, it may be dried to a moist condition in air or a drying apparatus not to exceed 140°F (60°C) prior to sample selection (Note 1). A representative test sample to perform the pH test shall then be obtained with a sampler or by splitting or quartering.

3 Sample Preparation: (continued)

Note 1 – Samples dried in an oven or other drying apparatus at a temperature not exceeding 140°F (60°C) are considered to be air dried.

3.2 The portion of the sample selected for pH testing shall be separated into fractions by one of the following methods:

4. Determination of pH:

4.1 Place sufficient soil into a 100 ml glass beaker or other suitable container to fill to the 80 ml mark.

4.2 Stir a sufficient amount of distilled water into the sample to produce a soil slurry and then cover with a watch glass.

4.3 Let the sample stand for a minimum of one hour, stirring every 10 to 15 minutes. This is to allow the pH of the soil slurry to stabilize.

4.4 Measure the temperature of the soil and adjust the temperature controller of the Ph meter to that of the sample temperature. This adjustment should be done just prior to testing.

4.5 Stabilize the pH meter by means of the standard solutions provided.

4.6 Stir the sample with a glass rod immediately before immersing the electrode into the soil slurry solution and gently turn the beaker or container to make good contact between the solution and the electrode. **DO NOT** place the electrode into the soil, only into the soil slurry solution.

4.7 Immerse the electrode in the solution for at least 30 seconds to allow the meter to stabilize. If the meter has an auto read system, it will automatically signal when stabilized.

4.8 Read and record the pH value to the nearest tenth of a whole number.

4.9 Rinse the electrode well with distilled water, then dab lightly with tissues to remove any film formed on the electrode. ***Caution:*** *Do not wipe the electrode as this may result in polarization of the electrode and consequent slow response.*

4.10 Add approximately 1 gram of calcium carbonate ($CaCO_3$) to the soil slurry and set aside for approximately 24 hours and determine the marble pH according to sections 4.4 to 4.9.

5. Determination of Conductivity:

5.1 Place a sufficient amount of soil on a 100 mm watch glass to completely cover the watch glass and let stand overnight to allow the sample to dry.

5.2 Sieve the dry sample over a No. 10 sieve (2.00 mm) and then pulverize with a mortar and pestle in such a manner so as to break up the aggregations without fracturing the individual grains. If the sample contains brittle particles, pulverize carefully and with just enough pressure to free the finer material that adheres to the coarser particles.

5.3 Place a portion of the soil in a 100 ml beaker and add distilled water at a ratio of 1 part soil to 2 parts water and let stand for 30 minutes.

5.4 After conditioning, pour the water from the beaker into the sample container of the conductivity meter and determine the conductivity to the nearest 0.01 m. mhos.

6. Determination of Sulfate Content:

6.1 Place 3 grams of the remaining soil from the watch glass into a 500 ml Erlenmeyer flask.

6. Determination of Sulfate Content: (continued)

6.2 Add 150 ml of distilled water, stopper the flask and shake to mix.

6.3 Centrifuge the sample for 30 minutes.

6.4 Decant the liquid into a 250 ml beaker and add 2 ml of dilute Hydrochloric acid (50% strength), to flocculate the suspended particles, cover with a watch glass and place onto a hot plate until the sample boils.

6.5 Remove the beaker from the hot plate and immediately filter through a fast filter paper (Whatman #41)

6.6 Add 10 ml of a 10% Barium Chloride ($BaCl_2 \cdot 2H_2O$) solution to this sample to determine the presence of sulfate. *(The liquid will become milky in the presence of sulfate).*

6.7 Cover the beaker with a watch glass and return to the hot plate to boil.

6.8 Immediately filter through a slow filter paper (Whatman #42) and wash with several hot water rinses.

6.9 Place the filter paper in a tared 30 ml platinum crucible, place the crucible into a muffle furnace and slowly raise the temperature to 1000°C to burn off filter paper.

6.10 Remove from the muffle furnace and desiccate until cool. Weigh to the nearest 0.0001 grams and record.

7. Sulfate Calculation:

[(W x 0.4115) / S] x 100 = _____ % Sulfate (SO_4)

where:

W = Sulfate wt.

S = Soil sample wt.

8. Report:

pH - _____
Marble pH - _____
Sulfate - _____ % SO_4
Conductivity - _____ m. mohs

BACK

CURRENT DATE OF REVISION
MT-300 SECTION (BITUMEN-AGGREGATE)

Test Method No.	Title	Pages	Date of Publication or Revision
MT-301	Sieve Analysis of Mineral Filler and Hydrated Lime	pp 1-2	May 2004
MT-302	Sampling Bituminous Materials	pp 1-4	May 2004
MT-303	Sampling Bituminous Paving Mixtures	pp 1-3	May 2004
MT-304	Moisture Test of Plant-Mix Bituminous Aggregates	pp 1-2	May 2004
MT-305	Volume Swell of Bituminous Mixtures	pp 1-5	May 2004
MT-306	Marshall Method for Bituminous Mix Design	pp 1-11	May 2004
MT-307	Centrifuge Extraction of Bituminous Mixes	pp 1-4	May 2004
MT-308	Temperature/Viscosity Charts	pp 1-4	May 2004
MT-309	Reducing Samples of Hot Mix Asphalt to Testing Size	pp 1-2	May 2004
MT-310	The Determination of Bituminous Aggregate Treatments	pp 1-2	May 2004
MT-311	Marshall Method for Field Control of Hot Mix Asphalt Paving	pp 1-6	May 2004
MT-312	Determining Moisture Content of Bituminous Mixtures	pp 1-2	May 2004
MT-313	Procedure for Comparing Nuclear Gauge to Core Densities of Bituminous Paving Mixtures	pp 1-3	May 2004
MT-314	Method of Test for Bulk Specific Gravity of Compacted Bituminous Mixtures	pp 1-4	May 2004
MT-315	Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens	pp 1-8	May 2004
MT-316	Method of Sampling Recycled Pavement and Field Control of Recycle Paving	pp 1-5	May 2004
MT-317	Procedure for Monitoring In-Place Bituminous Pavement Density and Air Voids	pp 1	May 2004
MT-318	Using Dry Ice to Obtain Cores From Hot Plant Mix Surfacing	pp 1-2	May 2004
MT-319	Determining the Asphalt Binder Content of Hot Mix Asphalt (HMA) By the Ignition Method	pp 1-6	May 2004
MT-320	Mechanical Analysis of Aggregate Recovered from Ignition Oven Burn	pp 1-3	May 2004
MT-321	Procedure for Determining Maximum Specific Gravity of Bituminous Paving Mixtures - "Rice Method"	pp 1-3	May 2004
MT-322	Vacant		
MT-323	Fabricating Specimens for Compressive Strength of Bituminous Mixtures	pp 1-3	May 2004
MT-324	Effect of Water on Cohesion of Compacted Bituminous Mixtures	pp 1-3	May 2004
MT-325	Method of Determining Moisture Content of Bituminous Mixtures or Aggregate Using Microwave Ovens	pp 1-3	May 2004

Test Method No.	Title	Pages	Date of Publication or Revision
MT-326	Method of Sampling and Testing To Determine the Plane of Failure in Rutted Asphalt Pavements	pp 1-2	May 2004
MT-327	Mechanical Analysis of Extracted Aggregate	pp 1-4	May 2004
MT-328	Vacant	pp 1-2	May 2004
MT-329	Procedure for Evaluating Plant Mix Surfacing Failures	pp 1-5	May 2004
MT-330	Resistance of Compacted Bituminous Mixtures to Moisture Induced Damage	pp 1-4	May 2004
MT-331	Method of Sampling and Evaluating Stripping Pavements	pp 1-2	May 2004
MT-332	Gyratory Compaction of Bituminous Mixtures	pp 1-6	May 2004
MT-333	Method of Test for the Torsional Recovery of Latex Modified Asphalt Emulsion Residue	pp 1-3	May 2004
MT-334	Method of Test for Hamburg Wheel-Track Testing of Compacted Bituminous Mixtures	pp 1-3	May 2004
MT-335	Linear Kneading Compaction of Bituminous Mixtures	pp 1-2	May 2004

METHODS OF SAMPLING AND TESTING
MT 301-04
METHOD OF TEST FOR
SIEVE ANALYSIS OF MINERAL FILLER AND HYDRATED LIME

1 Scope:

1. This method of test covers the sieve analysis of mineral fillers and hydrated lime used in road and paving materials.

2 Apparatus:

2.1 *Balance* – The balance shall be sensitive to 0.1 grams.

2.2 *Sieves* – The sieves shall conform to MT-405 (Sieves for Testing Purposes), and shall include the 30 mesh (0.600 mm) sieve, the 80 mesh (0.180 mm) sieve, and the 200 mesh (0.075 mm) sieve.

2.3 *Oven* – The oven shall be capable of maintaining a temperature of 230 ± 9ºF (100 ± 5ºC).

2.4 *Container* – A pan or vessel of a size sufficient to contain the sample covered with water and to permit vigorous agitation without inadvertent loss of any part of the sample or water. A stainless steel container with a diameter of approximately 9 inches, a height of approximately 10 inches, and a convenient handle has been found satisfactory).

3 Sample:

3.1 Thoroughly mix the mineral filler or hydrated lime in the field sample and then obtain a test sample for sieve analysis using a spoon or small scoop. A minimum mass of approximately 100 grams of dry material is required for each test.

4 Procedure:

4.1 After drying the test sample to constant mass at a temperature of 230 ± 9ºF (110 ± 5ºC) and weighing to the nearest 0.1 gram, the sample shall be placed in the container and covered with sufficient water to assure a thorough separation of the material finer than the 200 mesh (0.075 mm) sieve from the coarser particles. The contents of the container shall be agitated vigorously and the wash water poured immediately over a 200 mesh (0.075 mm) sieve.

Note 1 – A spray nozzle or a piece of rubber tubing attached to a water faucet may be used for the washing. The velocity of the water, which may be increased by pinching the tubing, shall not be sufficient to cause any splashing of the sample over the sides of the sieve.

4.2 The agitation should be sufficiently vigorous to result in the complete separation, from the coarse particles, all particles finer than the 200 mesh (0.075 mm) sieve, and bring the fine material into suspension in order that it will be removed by decantation of the wash water. Care should be taken to avoid, as much as possible, the decantation of the coarse particles of the sample. The operation shall be repeated until the wash water is clear.

Note 2 – the lack of adequate water pressure for agitation in the field test trailers allows for slight finger manipulation of the sample in the wash container to insure adequate separation of material finer than the 200 mesh (0.075 mm) from the coarser material. However, care must be taken to avoid the breaking down of larger particles. Under no circumstances is finger manipulation of the sample on the sieves allowed.

4.3 All material retained on the 200 mesh (0.075 mm) sieve shall be returned to the washed sample. The washed sample shall be dried to constant mass at a temperature of 230 ± 9ºF (110 ± 5ºC) and weighed.

4 Procedure: (continued)

4.4 Sieve the washed sample over a nest of sieves consisting of the 30 mesh (0.600 mm), 80 mesh (0.180 mm), and 200 mesh (0.075 mm). The weights of material retained on each of the above sieves shall be calculated as a percent of the original sample.

5 Report:

5.1 Report the results of the sieve analysis as the total percentage passing each sieve, expressed to the nearest 0.1 percent.

METHODS OF SAMPLING AND TESTING
MT- 302-04
SAMPLING AND TESTING PROCEDURE FOR BITUMINOUS MATERIAL

1 Scope:

1.1 This procedure is to give instructions on the uniform practices for sampling and testing bituminous materials, submitting samples, retaining samples, precautions to be used during sampling, designating who is to take the sample and the recording of information pertinent to the acceptance of bituminous materials.

1.2 Sampling of asphalt cement for Quality Assurance Specification projects and for projects not under the Quality Assurance Specification is described in this procedure. See Special Provisions to determine whether the project is under the Quality Assurance Specification.

1.3 The following described procedures and practices shall also apply to shipments of bituminous materials to be used by Maintenance.

2 Details of Sampling Procedures: *WHEN, WHERE and FREQUENCY.*

2.1 Cut Back Asphalts, Emulsions and Asphalt Cement (not under Quality Assurance Specification).

2.1.1 *Cut-Back Asphalts and Asphalt Cement:* Sampling of shipments of less than 2,000 gallons is not required unless deemed necessary by the engineer. In this case, forward a copy of the certificate of compliance to the Materials Bureau. Obtain duplicate samples of bituminous material from each shipment in excess of 2,000 gallons delivered at the time of discharge into distributors or other conveyance or storage tanks on the project. Reference to a shipment of bituminous material includes the truck and trailer. Obtain the two samples from only one of the units. However, the duplicate samples represent no more than the amount of bituminous material in the shipment from which they are taken.

2.1.2 *For Maintenance:* Deliveries of less than 2,000 gallons will be permitted when discharged directly into Department of Transportation equipment, i.e., State distributors and "tar pots". Sampling of these deliveries is not required unless specifically requested by the Maintenance Engineer.

2.1.3 *Emulsions:* All emulsion shipments will be sampled, regardless of the size of the shipment, within a reasonable time **(within 24 hours) upon arrival**. Remix the material by agitation, circulation, or storage transfer, and re-sample when the material is stored without agitation for three or more days before use. Specifications allow storage instability, in terms of the settlement test, of 3% and 5% for anionic and cationic emulsions, respectively. Emulsions in compliance with the stability test can still separate into denser and lighter layers (without breaking) in a few days of dead storage so that the material will not be uniform and other tests such as viscosity and asphalt content may not be in compliance with the specifications. Acceptance will be based on the specification compliance of the material immediately prior to use.

2.2 *Asphalt Cement (under Quality Assurance Specification)* - Asphalt cement used in Plant Mix Bituminous Surfacing, Open Graded Friction Course, and Plant Mix Bituminous Base will be sampled for acceptance from the line conveying asphalt cement from the storage facilities to the mixing plant. Duplicate samples are not necessary for projects falling under the Quality Assurance Specification. Frequency will be as indicated in MT-601.

3 Supervision:

3.1 The Department reserves the right to witness the taking of any or all acceptance samples by the Contractor or designated personnel.

4 Actual Sampling:

4.1 *Importance of proper sampling.* Sampling is equally as important as the testing, and every precaution shall be taken to obtain samples that will show the true nature and condition of the materials they represent. Test results are valuable only when the tests are performed on a sample truly representative of the material under consideration. Take samples in accordance with the following described procedures, so there will be no question about them being valid from that standpoint. This can become very important in case of a test failure, which may be the basis for rejection of the material.

4.2 Cut-Back Asphalt, Asphalt Emulsions and Asphalt Cement (not under Quality Assurance Specification).

4.2.1 Take a minimum of two (duplicate) one-quart samples in containers furnished by the State. Do not use second-hand containers or any containers washed or rinsed with solvents. Refer to note.

NOTE: USE METAL CONTAINERS FOR CUT-BACK ASPHALT AND ASPHALT CEMENT. USE PLASTIC CONTAINERS FOR ASPHALT EMULSIONS ONLY.

4.2.2 Samples of asphalt emulsions shall be taken in clean, one-quart plastic jars.

4.2.3 When feasible, all truck tanks, trailer tanks, or other conveyances containing bituminous materials shall be equipped with a sampling valve not less than 3/8 inch or more than ¾ inch in diameter. These valves may be installed either through the tank's bulkhead at centerline or on the discharge line between the truck unloading pipe and the hose. Sample the contents of railroad tank carts and truck transports, not equipped with a sampling valve, from the pressure side of the unloading pump. (See 4.2.4 below.)

4.2.4 Sample the full transport tank when sampling from the valve at the centerline of the tank's bulkhead. When sampling from the valve on the discharge line or from the pressure side of the unloading pump, sample after at least one-third of the tank has been discharged.

4.2.5 Discharge at least one gallon of the material through the valve prior to taking the samples. This procedure is very important to insure the taking of a representative and uniform sample.

4.2.6 Take the duplicate samples consecutively with a minimum lapse of time.

4.2.7 Leave the screw caps loose until the contents cool so the contraction of the asphalt will not collapse the containers. Remove any spillage on the outside of the container with a clean, dry cloth, cotton waste or paper towels. In no case should solvent (diesel fuel, gasoline, etc.) be used for this purpose. The fumes from a solvent will actually decrease the flash-point beyond the point of acceptance.

4.3 Asphalt Cement (under Quality Assurance Specification).

4.3.1 Sampling shall be done according to Section 4 – Actual Sampling, except that duplicate samples need not be taken and the contractor shall provide a device suitable for obtaining samples representative of the asphalt cement entering the mixing unit. A suitable in-line sampling device is shown in AASHTO T 40, Fig 5. Insert the sampling device into a rising section of the pipeline conveying asphalt cement from the storage facilities to the mixing plane or in a completely filled line in which gravity creates the materials flow. Turn the sampling device to face the flow of the liquid. The outlet valve may be in a horizontal or vertical position. The vertical position is preferred.

5 Submitting, Reporting and Testing of Samples:

5.1 Submitting:

5.1.1 When duplicate samples are taken, forward one of the samples (both samples in the case of asphalt emulsions), immediately to the Materials Bureau for testing. Retain the second sample for a later check test, in the event results on the first sample indicates noncompliance. This retained

5.1 Submitting: (continued)

sample should not be submitted unless requested by the Materials Bureau. Discard the retained sample after acceptable test results have been reported to the field.

5.2 Reporting:

5.2.1 Submit the samples with lab Form 101-C, Asphaltic Materials Report or CB57, Quality Assurance form. Use a separate form for each type or grade of asphalt used. Several samples of any one grade can be included on one form. The information to be included on the form is self-explanatory. The space for Date Received, Lab No., Viscosity, Penetration and Flash are to be left blank for use by the Materials Bureau.

5.2.2 Always note the last sample on any one grade as "Final" on the tag and Lab Form.

5.2.3 Place Lab Form 101-C in the plastic envelope with the samples in the shipping box.

5.2.4 Attach an identification tag, Form 91, to each sample. In addition, mark each sample container with a wax pencil, crayon or "Marxall" type of marking instrument in case the identification tag is lost through destruction, detachment or obliteration. Include the following information: Project No., Q.A. or Non-Q.A., Sample No. (see MT-512 about sampling numerical sequence), Gallons, Asphalt Type, Manufacturer, Invoice No., Specific Gravity, project Manager and Date. It is important that none of the information be omitted.

5.3 Testing:

5.3.1 The materials Bureau will make the identification tests (Flash Point and Viscosity) on each of the original samples. Complete tests for all specification requirements will be conducted, on samples selected at random for each project, by the Materials Bureau.

5.3.2 When the result of any one test on the first sample is not within the specification limits, without the application of any tolerance, the Materials Bureau will immediately notify the Prime Contractor and the Project Manager.

5.3.3 The material represented by the sample will be considered satisfactory and acceptable if the retained sample tests are satisfactory. If the retained sample also fails to meet the specification requirement, a schedule of tolerances may be applied to the specification requirement to determine whether the material may be acceptable for use without a reduction in price.

5.3.4 Upon completion of testing, the Materials Bureau will forward the results to the Engineering Project Manager by computer or on copies of Lab Form 101-C or CB57, Quality Assurance forms as submitted form the field. The laboratory will select at random the samples for complete testing and the complete test results will be reported to the field on the computer or Lab Form 101-B.

6 Certification of Shipments:

6.1 Suppliers of bituminous materials shall furnish the Project Manager, or his representative, one copy of the original bill of lading or invoice and a certificate if compliance, these documents are to accompany each tank car, truck-trailer tank, or other individual conveyance of bituminous materials shipped, or hauled to the project. This certificate, signed by a supplier's responsible representative, shall attest to the fact that the bituminous material complies with the Department of Transportation specifications for the type and grade of material represented and the conveyance was inspected and found to be free of contaminating material.

6.2 The certificate of compliance will be the basis for tentative acceptance and use of the material. In no instance may the shipment be tentatively accepted or incorporated in the work without the receipt of the certification. It may be included on the bill of lading or invoice or it may be a separate document attached to the bill of lading. The Project Manager will retain the certificate and bill of lading in the project files for record purposes.

METHODS OF SAMPLING AND TESTING
MT 303-04
METHOD OF SAMPLING BITUMINOUS PAVING MIXTURES
(Modified AASHTO T 168)

1 Scope:

1.1 These methods cover sampling of bituminous paving mixtures at points of manufacturer, storage, or delivery.

2 Referenced Documents:

2.1 *AASHTO Standards:*
T-168 Sampling Bituminous Paving Mixtures

MT Manual:
MT-309 Reducing Hot Mix Asphalt to Testing Size

WAQTC:
TM5

3 Securing Samples:

3.1 Sampling is equally important as the testing, and the sampler shall take every precaution to obtain samples that yield an acceptable estimate of the nature and conditions of the materials that they represent.

4 Inspection:

4.1 The material shall be inspected to determine discernable variations. The contractor shall provide equipment needed for safe and appropriate inspection and sampling.

5 Sampling:

5.1 *Sampling from a Conveyor Belt* - Stop the conveyor belt. Randomly select at least three areas of approximately equal size on the belt for sampling. In each of the locations to be sampled, insert templates, the shape of which conforms to the shape of the belt. From the selected areas obtain approximately equal increments of material that will form a sample whose quantity equals or exceeds the minimum recommended in 5.8.2. Carefully scoop all material between the templates into a suitable container.

5.2 *Sampling from Truck Transports or Paver Hoppers* - Select the units to be sampled from the production of materials delivered. Obtain at least four approximately equal increments, selected at random, from the unit being sampled and combine to form a field sample whose quantity equals or exceeds the minimum recommended in 5.8.2. The sample may be obtained by collecting the increments with a scoop or shovel. *NOTE: Avoid sampling the extreme top surface.*

5.3 *Sampling from a Paver Auger* – Obtain samples from the end of the auger, using a square point shovel. Place the shovel in front of the auger extension, with the blade flat upon the surface to be paved over. Allow the front face of the auger stream to cover the shovel, and remove the shovel before the auger reaches the shovel by lifting it upward as vertically as possible. Obtain approximately equal increments of material that will form a sample whose quantity equals or exceeds the minimum recommended in 5.8.2.

5.4 *Sampling form the Roadway Prior to Compaction* - When only one sample is to be taken, obtain at least three approximately equal increments, selected at random, from the unit being sampled and combine to form a field sample whose quantity equals or exceeds the minimum recommended in 5.8.2.

5 Sampling:(continued)

5.4.1 When three or more samples are to be taken in order to evaluate a lot of material, utilize a random method to select the locations to be sampled. Select a sample from each location; assuring the quantity of each sample exceeds the minimum recommended in 5.8.2.

5.4.2 Take all increments or samples from the roadway for the full depth of the material, taking care to exclude any underlying material. When necessary, place templates on the existing roadway to exclude any underlying material. Clearly mark the specified area from which each increment of sample is to be removed. Templates, which are placed before the mixture is specified, will be a definite aid in securing approximately equal increment weights.

5.5 *Sampling from a Skip Conveyor Delivering Mixture to Bin Storage* - Select the units to be sampled from the skip conveyor by a random method based on the bin's storage capacity. Stop the skip conveyor immediately following pug mill discharge. Dig a furrow 6 in. deep extending from the top to the bottom of the pile. Obtain three approximately equal increments from the top, middle, and bottom of the furrow, depositing each portion in a container. The combined portions should form a field sample whose quantity equals or exceeds the minimum recommended in 5.8.2.

5.6 *Sampling from a Funnel Device Feeding a Conveyor for Mixture Delivery to Storage*: Select the units to be sampled from the funnel device by a random method based on the bin's maximum storage capacity. Obtain at least three approximately equal increments of material for each sample by passing a bucket or pan or other suitable container across the full flow of the material as it drops from the funnel device onto the conveyor. The combined portions should form a filed sample whose quantity equals or exceeds the minimum recommended in 5.8.2.

5.7 *Sampling from the Roadway after Compaction* - Select the units to be sampled from the funnel device by a random method from the material in place. Obtain at least three approximately equal increments selected at random from the unit being sampled. Test each increment and average the test results to determine the acceptability. Take all the increments from the roadway for the full depth of the material, taking care to exclude any underlying material. Each increment shall be obtained by coring, sawing, or other methods in such a manner as to ensure a minimum of disturbance of the material.

5.8 ***Number and Quantities of Field Samples***:

5.8.1 The number of field samples (obtained by one of the methods described in 5) required depends on the criticality of, and variation in, the properties to be measured. Designate each unit from which a field sample is to be obtained prior to sampling. The number of field samples from the production should be sufficient to give the desired confidence in test results.

5.8.2 A guide to the quantity of material in field samples is given in Table 1. The quantities depend on the type and number of tests to which the material is to be subjected, and sufficient material must be obtained to provide for the proper execution of standard control and acceptance tests.

Table 1 – Guide for Estimating the Quantity of Sample

Nominal Maximum Size of Aggregates	Approximately Weight of Uncompacted Mixture, Min. lb (Kg)	Approximate Area of Compacted Mixture, Min. in² (cm²)
No. 8 (2.36 mm)	4 (1.8)	36 (232)
No. 4 (4.75 mm)	4 (1.8)	36 (232)
3/8 in. (9.5 mm)	8 (3.6)	36 (232)
1/2 in. (12.5 mm)	12 (5.4)	64 (413)
3/4 in. (19.0 mm)	16 (7.3)	100 (645)
1 – in. (25.0 mm)	20 (9.1)	144 (929)
1 ½ in. (38.1 mm)	25 (11.3)	144 (929)
2 – in. (50.0 mm)	35 (15.9)	255 (1453)

- **Nominal maximum size – One sieve size larger than the first sieve to retain more than 10 percent.**

5.8 ***Number and Quantities of Field Samples***: (continued)

Monitor samples for testing should be obtained from the field sample by quartering or splitting and require an additional sixteen (16) lbs. of material.

6 Shipping Samples:

6.1 Transport samples in containers constructed to preclude loss or contamination of any part of the sample, or damage to containers from mishandling during shipment.

6.2 Samples shall have individual identification attached giving the information required by the sample user. Typical information that may be useful could include, but not necessarily be limited to the following:

6.2.1 The project for which the material is to be used, giving the project number, highway route number, county, and other pertinent geographical information.

6.2.2 Source of the sample, including for plant-mix samples the name of the owner or operator of the plant, the location of the plant, type of plane, size of batch, and identification of the bitumen and mineral aggregates used in the mixture.

6.2.3 For samples taken from the roadway, include both the station number and the location transversely in the pavement, also whether sample from completed pavement, windrow, etc.

6.2.4 Quantity represented.

6.2.5 Name and title of the person taking the sample.

6.2.6 Date of most recent mixing, if road-mixed.

6.2.7 Date sampled.

6.2.8 Name and address of the person submitting the sample.

6.2.9 Purpose for which the sample was taken.

6.2.10 To whom the report is to be made.

6.2.11 Completed form 98.

METHODS OF SAMPLING AND TESTING
MT 304-04
MOISTURE TEST ON PLANT MIX BITUMINOUS SURFACING AGGREGATES
(Montana Method)

1 Scope:

1.1 This procedure is to be followed in sampling and testing plant mix bituminous surfacing aggregates for moisture content. This method is to serve as a guideline to control the variable moisture content.

2 Procedure:

2.1 Obtain a representative sample of at least 1.36 kilograms (three pounds) from each bin. Immediately place the material, from each separate bin, into a weighed container and seal.

2.2 After weighing the container with aggregate, transfer the material to drying pans and dry to constant weight in an approved manner. The sample should be stirred occasionally to facilitate drying, which should proceed for at least an hour.

2.3 On completion of the drying process, reweigh sample and container.

2.4 Compute the moisture content of each sample of the aggregate using the following formula:

$$M = \frac{W - D}{D - C} = 100$$

where:

M = percent of moisture

W = wt. of wet sample and container

D = wt. of dry sample and container

C = wt. of container

2.5 Compute the composite moisture content of the total aggregate according to the following example:

Aggregate Size	Fraction of Job Mix		Moisture Content, Percent
3/4" to 3/8"	.20	x	2.00 = 0.40
3/8" to No. 10	.40	x	1.00 = 0.40
Passing No. 10	.40	x	0.50 = 0.20
	Composite Moisture Content		= 1.00

2.6 A composite moisture content should be determined after the plant has attained a steady rate of production.

3 Additional Tests:

3.1 If the composite moisture content is not excessive, no additional tests will be required unless plant production rate is greatly increased, moisture content of the aggregate source increases, or if any of the following conditions arise:

3 **Additional Tests:** (continued)

3.1.1 Foaming on the surface of the coarse aggregate particles,

3.1.2 Excessive slumping of the mix in the truck,

3.1.3 Condensed water dripping from the truck box, and

3.1.4 Bubbles or blisters forming on the surface immediately behind the paver.

3.2 Ordinarily these conditions will not develop if the moisture content is below approximately 2 percent.

4 **Corrective Action:**

4.1 If a test reveals excessive moisture content, corrective action is to be taken at once and the Construction Bureau is to be notified immediately by telephone.

METHODS OF SAMPLING AND TESTING
MT 305-04
METHOD OF TEST FOR VOLUME SWELL OF BITUMINOUS MIXTURES
(Montana Test Method)

1 Scope:

1.1 This test method provides for the determination of the maximum volume swell of compacted aggregates, soil, sand, or combination of mixtures passing the 10 Mesh (2.0 mm) sieve and stabilized with bituminous material.

2 Apparatus:

2.1 *Compaction Apparatus:*

2.1.1 *Forming mold* - This forming mold shall be a steel cylinder 2.50 inches (63.5 mm) or greater in outside diameter, 2.000 - 2.001 inches (50.80 - 50.8254 mm) inside diameter, and approximately 2.75 inches (69.85 mm) high. One end shall be recessed 0.245 - 0.250 inches (6.223 - 6.350 mm) with an inside diameter of 2.250 - 2.252 inches (57.1500 - 57.2008 mm) to fit the 2.247 - 2.249 inch (57.0738 - 57.1246 mm) base if the base plate method is used.

2.1.2 *Plungers* - Cylindrical steel plungers, fitted to the molding cylinders, 1.997 ± 0.001 inch (50.7238 ± 0.0254 mm) in diameter and 3 inches (76.2 mm) high.

2.1.3 *Base* - Solid steel, circular plate 1 inch (25.4 mm) thick and 3 inches (76.2 mm) in diameter, beveled and machined to a 2.247 - 2.249 inch (57.0738 - 57.1246 mm) top diameter above the mold seat.

2.2 *Compression Testing Machine or Press* - A compression machine or press capable of applying loads of 10,000 pounds (4535.9 kg.) or greater and indicating the applied load with a sensitivity of 50 pounds (22.7 kg.) or less.

2.3 *Mixing Apparatus:*

2.3.1 *Mixing pans* - shall be smooth and conform to the following dimensions:
Bottom inside diameter = approximately 4-3/4" (120.65 mm)
Top inside diameter = approximately 6-1/4 in. (158.75 mm)
Height = approximately 3 in. (76.2 mm)

2.3.2 *Spatula* - approximately 7 in. (177.8 mm) long and 1/2 in. (12.7 mm) wide.

2.3.3 *Putty knife* - approximately 1-1/2 in. (38.1 mm) wide with a rounded tip.

2.3.4 Large metal scoop with handle.

2.3.5 Anti-slip, flexible rubber gloves

2.4 *Heater* - An electrical hot plate for warming pans of bituminous mix.

2.5 *Vacuum Desiccator* - of convenient size with a vacuum gauge incorporated on the lid. The gauge shall be calibrated in inches or centimeters of Hg (mercury) vacuum.

2.6 Hand or motor driven vacuum pump with approximately two feet of plastic vacuum hose.

2.7 Stop-cock grease for desiccator seal.

2 Apparatus: (continued)

2.8 Screw clamp.

2.9 Measuring and weighing apparatus.

2.9.1 A balance with a capacity of 500 grams and sensitive to 0.1 grams or less with a weighing scoop approximately 11 x 6 x 2-3/4 in. (279.4 x 152.4 x 69.85 mm), having a circular foot base, and equipped with a counter weight.

2.9.2 A measuring device that is accurately calibrated and equipped to determine heights and diameters of test specimens to the nearest 0.01 cm.

2.9.3 *Mercury Displacement Cup* - A glass or plastic cup with flat ground edge of convenient size to contain test specimens for mercury displacement measurement.

2.9.4 Glass dish approximately 10 x 6 x 2 in. (254 x 152.4 x 50.8 mm)

2.9.5 Porcelain pan approximately 15 x 10 x 2-1/2 in. (381 x 254 x 63.5 mm)

2.10 Drying Oven - A drying oven capable of maintaining a temperature of 140± 5°F (60 ± 3°C)

2.11 A 4 mesh (4.75 mm) and a 10 mesh (2.0 mm) sieve.

2.12 Thermometers, beakers, and a 100 ml, glass, graduated cylinder with intervals of 1.0 mm.

2.13 Pulverizing Apparatus - Either a mortar and rubber covered pestle or a mechanical device consisting of a power-driven rubber covered muller suitable for breaking up the aggregations of soil particles without reducing the size of the individual grains.

3 Materials:

3.1 Distilled water with a pH of approximately 7. (Tap water is satisfactory if it does not interfere chemically with the test.)

3.2 Bituminous material - 200/300 Pen A.C.

3.2.1 200/300 Pen A.C. should be replaced with new asphalt at the beginning of each construction season.

3.3 Mercury.

4 Preparation of Aggregate:

4.1 A representative sample of the 10 mesh (2.00 mm) material as described in MT-200 (Dry Preparation of Aggregate) shall be prepared. The sample shall be large enough to produce approximately 400 grams of minus 10 mesh (2.00 mm) material at the conclusion of the pulverizing procedure.

5 Preparation of Bituminous Mix and Test Specimen:

5.1 Warm the 200/300 Pen Asphalt Cement for mixing to approximately 250 15ºF (121± 8ºC).

5.2 Stabilize the hot plate at 425 to 475ºF (218 to 246ºC).

5 Preparation of Bituminous Mix and Test Specimen: (continued)

5.3 Stir the sample prepared in paragraph 4 with a spatula and transfer a 100 gram sample to the weighing scoop. Use the spatula to obtain a uniform discharge and to pull material from the bottom of the sample container when transferring the material. If desired, the material may be preheated in an oven 230± 9ºF (110± 5ºC).

5.4 Transfer the 100 gram sample from the weighing scoop to the mixing pan, stir with a putty knife and shake the material to one side of the mixing pan.

5.5 Place the mixing pan and sample on the balance and add 6.5 grams of 200/300 Pen A.C., do not pour asphalt on material; place the pan back on the hot plate.

5.6 When asphalt starts to flow into the sample, start mixing rapidly with a putty knife while shaking the mixing pan close to the hot plate. Avoid overheating the mix, as evidenced by smoking asphalt. Mix and shake until a thorough mixture is obtained. (See Note 1).

NOTE 1 - In the case of material having poor adhesion, the larger particles will only be slightly coated. Do not add more asphalt. Mix and shake until maximum coverage is obtained.

5.7 Pour the mixture from the mixing pan into a small scoop. Pour the mixture from the scoop into the assembled mold using the spatula to assist in obtaining a uniform discharge from the scoop. Insert the top plunger with a twist and a light tamp to seat firmly. Place the mold in the compression machine and at a uniform rate increase the load to a total of 6280 pounds in no less than 15 seconds. Maintain the maximum load for one minute and release. Remove the base plate with a twisting motion and mark the briquette in the mold with a wax crayon, applying light pressure.

5.8 After removing the base plate with a twisting motion and marking the briquette, turn the assembly upside down. Place the sleeve on top of the forming mold and using the jack apply pressure to the sleeve and top plunger. This will push the briquette and top plunger up into the sleeve. (See Note 2). Cool and cure the briquette for three hours at room temperature.

NOTE 2 - If the briquettes tend to stick to the mold or plungers, preheat mold to 140ºF (60ºC).

5.9 Wipe the forming mold, base plate and plungers clean with a suitable solvent and dry with a cloth before forming each briquette.

5.10 Record the dimensions of the briquette at the end of the three-hour cure. Dense briquettes are measured with either calipers or the mercury displacement method. (See Note 3).

NOTE 3 - Porous briquettes that may entrap mercury shall be measured with calipers only.

6 Twenty-Four Hour Volume Swell Procedure:

6.1 Prepare a briquette in the manner described in paragraph 4 and paragraph 5.1 – 5.10. The briquette will be tested as follows:

6.2 Check the vacuum equipment for leaks before any briquettes are put into the desiccator.

6.3 Fill the vacuum desiccator with distilled water and allow to stabilize at room temperature. Completely submerge the briquette in the distilled water and seal the top.

NOTE 4 - A perforated tray is supplied for a second layer of briquettes.

6 Twenty-Four Hour Volume Swell Procedure: (continued)

6.4 Subject the briquette to 8 inches (20.3 cm) of mercury vacuum for one hour. The 8 inches of vacuum will be applied within the desiccator in not less than one minute. The vacuum is maintained for one hour and released gradually to avoid pressure shock to the briquettes.

6.5 Keep the briquette completely submerged in the distilled water at room temperature for an additional 23 hours. If necessary to transfer to another container of distilled water, wait 15 minutes after releasing pressure before effecting transfer.

6.6 Remove the briquette, blot the excess water and weigh. (See Note 3). In no event will the briquette be allowed to set for more than ten minutes before weighing is completed. The sides of the briquette will be squeezed for recording condition of the briquette such as hard, firm, soft, soft and cracked, or disintegrated. Refer to paragraph 7 (calculations) to determine the percent of volume swell. (See Notes 4 & 5)

NOTE 5 - The test specimen shall be measured immediately after excess water is blotted off the specimen. When measuring with calipers, take four measurements on the sides of the specimen and four measurements on the flats of the specimen at 90 degree intervals and record. The average of the recordings will be used for the calculation. If the specimen is allowed to set for any amount of time, the specimen will dry out and shrink giving erroneous swell results.

NOTE 6 - Mercury (Hg) is a poison and can be absorbed through the respiratory tract, the intestinal tract or through unbroken skin. Mercury is a cumulative poison and is a very volatile element. Dangerous levels are readily attained in air at 77°F (25°C). Tests involving the use of mercury should be performed under conditions of adequate ventilation. A fume hood is recommended for large numbers of samples or where the test is to be carried out frequently over extended periods of time. Protective gloves should be worn under conditions where skin contact with mercury may occur.

7 Calculation:

7.1 The volume swell, expressed as a percentage can be calculated by either of the two following methods.

7.1.1 Weight of Mercury

$$S = \frac{W_2 - W_3}{W_1 - W_2} x100$$

where:

S = volume swell, percent,

W_1= weight of cup filled with mercury,

W_2= weight of mercury and cup minus mercury lost because of immersion of cured briquette,

W_3= weight of mercury and cup minus mercury lost because of immersion of swollen briquette.

7 Calculation: (continued)

7.1.2 Volume of Specimen by Calipers

$V = \pi r^2 h$

where:

V = volume of specimen

π = 3.1416

r = radius of specimen

h = height of specimen

and

$$S = \frac{V_2 - V_1}{V_1} x100$$

where:

S = volume swell, percent,

V_1 = volume of specimen before immersion, by caliper

V_2 = volume of specimen after immersion.

8 Report:

8.1 The report shall consist of the following:

8.1.1 Percent of Volume Swell,

8.1.2 Condition of specimen.

METHODS OF SAMPLING AND TESTING
MT 306-04
MARSHALL METHOD FOR BITUMINOUS MIX DESIGN

GENERAL

1 Scope:

1.1 The Marshall method may be employed for specifying, obtaining and maintaining the best possible physical or structural properties of the paving mixture. To achieve these objectives, the test is applied in the following ways:

2 Application:

2.1 Determine the limits for specifications, with reference to gradation and aggregate source proposed for use, to produce the most satisfactory physical properties.

2.2 Design the paving mixture from the materials proposed for use in order that the requirements will be determined before plant production starts.

3 Maximum Size Aggregate:

3.1 The Marshall method as presented here is applicable only to hot-mix asphalt paving mixtures using penetration grades of asphalt cement and containing aggregates with maximum size of one inch or less.

4 Preliminary Requirements:

4.1 The procedure for the Marshall method starts with the preparation of test specimens. Preliminary to this operation it is, of course, required that:

4.2 The material proposed for use must meet the requirements of the project specifications.

PREPARATION OF TEST SPECIMENS

5 General:

5.1 In determining the optimum asphalt cement for a particular gradation of aggregates by the Marshall method, a series of test specimens is prepared for a range of different asphalt contents so that the test data curves show a well-defined "optimum" value. Tests should be scheduled on the basis of one-half of one percent increments of asphalt contents, with at least one asphalt content above "optimum" and at least one asphalt content below "optimum."

6 Number of Specimens:

6.1 To provide adequate data, three test specimens are prepared for each asphalt content used. Thus, a hot-mix design study using five different asphalt contents, based on ½% increments with two on each side of the optimum asphalt content, will normally require fifteen test specimens. Each test specimen will usually require approximately 1100 to 1150 grams of aggregate

7 Equipment:

7.1 Pans, metal, flat bottom, for heating aggregates.

7.1.2 Pans, metal, round, approximately 4-quart capacity for mixing.

7 **Equipment:** (continued)

7.1.3 Oven and hot plate, electric, for heating aggregates, asphalt and equipment required.

7.1.4 Scoop, for batching aggregates.

7.1.5 *Containers* - gill-type, tins, beakers, pouring pots, for heating asphalt.

7.1.6 *Thermometer* - armored glass, or dial type with metal stem, +50°F to +450°F for determining temperature of aggregates, asphalt and aggregate mixtures.

7.1.7 *Balance* - 5 kg capacity, sensitive to 1 g, for weighing aggregates and asphalt. Balance, minimum 2 kg capacity, sensitive to 0.1 g, for weighing compacted specimens.

7.1.8 Mixing spoon or trowel.

7.1.9 Spatulas, large, stiff.

7.1.10 Boiling water-bath, consisting of hot plate and bucket for water, for heating compaction hammer and mold.

7.1.11 *Compaction pedestal* - consisting of an 8 inch x 8 inch x 18 inch wooden post capped by a 12 inch x 12 inch x 1 inch steel plate. The post should be placed on a 24 inch x 24 inch x 4 inch concrete block so it is plumb, the top is level, and the entire assembly is free from movement during use.

7.1.12 *Compaction mold* - consisting of a base plate, forming mold, and collar extension. The forming mold has an inside diameter of 4∀.005 inches and a height of approximately three inches; the base plate and collar are designed to be interchangeable with either end of the forming mold.

7.1.13 *Compaction hammer* - consisting of a flat, circular, tamping face 3-7/8 inches in diameter and equipped with a ten pound weight constructed to obtain a specified 18-inch height of drop.

7.1.14 *Mold holder* - consisting of a spring tension device designed to hold compaction mold in place on compaction pedestal.

7.1.15 *Extrusion jack, or arbor press* - for extruding compacted specimens from the mold.

7.1.16 Welders gloves for handling hot equipment and rubber gloves for removing specimens from water bath.

7.1.17 Marking crayons for identifying test specimens.

7.1.18 *Set of standard sieves* - 10 mesh (2.00 mm) to 1" (25.0 mm)

Note 1 -All laboratories are equipped with the Marshall Mechanical Compactor. These should be used in preference to hand compaction. It is essential that the mechanical compactor be placed on a foundation or base as described in paragraph 7.K. Double or triple hammer compactors will require an appropriately larger base than the one described.

8 **Preparation of Test Specimens:**

8.1 Number of specimens - Prepare at least three specimens for each combination of aggregates and asphalt.

8.2 Preparation of aggregates - Dry aggregates to constant weight at 230 ± 9°F (110 ± 5°C) and separate the aggregates by dry sieving into the desired size fractions.

8 Preparation of Test Specimens: (continued)

8.3 Mixing Temperature - Select the mixing temperature for asphalt required to produce a viscosity of 170 ± 20 C_{st} as obtained by using the temperature-viscosity charts in MT-308.

8.4 Compaction Temperature - Select the compaction temperature so that the viscosity of asphalt is 280 ± 30 C_{st} as obtained by using the temperature-viscosity charts in MT-308.

8.5 Preparation of mold and hammer - Thoroughly clean the specimen mold assembly and the face of the compaction hammer. Heat them in a boiling water bath or on the hot plate to a temperature between 200 and 300 F. Place a filter paper, cut to size, in the bottom of the mold before the mixture is placed in the mold.

8.6 Preparation of mixture - Weigh the quantity of each size of aggregate to produce a 63.5 ± 1.27 mm (2.5 ± 0.05 inches) high finished briquet. The total weight of aggregate is usually 1150 grams. Progressively combine these fractions into a single pan. (Note 2) Place the pan in an oven or on a hot plate and heat to a temperature approximately 28°C (50°F) above the mixing temperature specified in 8.3. Prevent local overheating. Dry mix the aggregate thoroughly, form a crater in the center and weigh the required asphalt cement into the crater. At this point, the temperature of the aggregate and asphalt shall be within the limits of the mixing temperature established in paragraph 8.3. Mix the asphalt and aggregate with a trowel or stiff spatula as quickly and thoroughly as possible to yield a mixture having a uniform distribution of asphalt throughout. (Note 3)

Note 2 - A mixture of aggregate shall be prepared without the minus 200 mesh and washed to determine the percentage of minus 200 mesh coating the coarser fractions. An adjustment shall be made for minus 200 mesh coating the coarser fractions when batching the other specimens.

Note 3 - In place of hand mixing, a mechanical mixer may be used, if it is available and provides thorough mixing without fracturing the aggregate.

9 Compaction of Specimens:

9.1 Place a piece of filter paper or paper toweling cut to size in the bottom of the mold before the mixture is introduced. Place a sufficient amount of the mixture, at the temperature prescribed in paragraph 8.4, in the mold to produce a compacted briquet approximately 63.5 ± 1.27 mm (2.5 ± 0.05 inches) high. Spade the mixture vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times through the interior. Care should be taken so that an excess of coarse aggregate is not segregated to the surface or the face of the specimen will be rough and have higher voids than the interior of the specimen.

9.2 Remove the collar and smooth the surface to a slightly rounded shape.

9.3 Replace the collar and place a filter paper on top of the mixture prior to compaction.

9.4 Place the mold assembly on the compaction pedestal in the mold holder and, unless otherwise specified, apply 50 or 75 blows with the compaction hammer, using a free fall of 18 inches. (Hold the axis of the compaction hammer perpendicular to the base of the mold assembly during compaction.)

9.5 Remove the base plate and collar, reverse and reassemble the mold.

9.6 Apply the same number of blows to the face of the reversed specimen.

9.7 After compaction is completed, air cool the specimen by the use of fans for 30 minutes.

9 Compaction of Specimens: (continued)

9.8 Remove the specimen from the mold by means of an extrusion jack or other compression device, and place on a smooth, level surface until ready for testing.

9.9 Form a second specimen, as rapidly as possible, in the same manner as described in paragraph 9.1 through 8.

TEST PROCEDURE

10 General:

10.1 In the Marshall method each compacted test specimen is subjected to the following tests and analysis in the order listed:

Bulk Specific Gravity Determination
Stability and Flow Test
Density and Voids Analysis

11 Equipment:

11.1 Water Bath - At least six inches deep and thermostatically controlled to 60 ± 1°C (140 ± 2°F). The tank should have a perforated false bottom or be equipped with a shelf for suspending specimens at least two inches above the bottom of the bath.

12 Bulk Specific Gravity of a Compacted Bituminous Test Specimen:

12.1 The bulk specific gravity of a compacted specimen may be obtained by computing the ratio of its weight in air to its bulk volume (including both permeable and impermeable voids normal to the material). Weighing the specimen in water then weighing the saturated surface-dry specimen in air, and calculating the difference may ordinarily determine the bulk volume. The equipment necessary to conduct this test is as follows:

12.1.1 *Balance* - A balance having a minimum capacity of 2 kg and sensitive to 0.1 g or less

12.1.2 *Wire basket* - A wire basket constructed to hold the test specimen while it is being weighed immersed in water.

12.1.3 *Container with overflow device* - For immersing the wire basket in water and maintaining a constant water level.

12.1.4 *Suspension apparatus* - For suspending the wire basket from the center of a scale pan of the balance.

12.1.5 *Cloth towel* - For blotting the excess water from the specimen after weighing in water.

12.2 Weigh the specimen in air on the balance to the nearest 0.1 g and record this weight as "A". Weigh the specimen suspended in the basket and immersed for three to five minutes in a water bath at 77°F (25°C). Weigh to the nearest 0.1 g and designate this weight as "C". Remove the specimen from the water, surface dry by blotting with a damp towel, weigh the surface-dry specimen in air to the nearest 0.1 g and designate this weight as "B".

12.3 Calculate the bulk specific gravity of the test specimen as follows:

$$\text{Bulk Specific Gravity} = \frac{A}{B - C}$$

12 Bulk Specific Gravity of a Compacted Bituminous Test Specimen: (continued)

where:

A = weight of specimen in air,

B = weight of saturated surface dry specimen in air and

C = weight of specimen in water

Note 4 - This method is applicable for relatively smooth, densely graded, non-absorptive compacted mixtures; with less than 2% absorption only. This method conforms to AASHTO T-166, Method A.

13 Stability and Flow Tests:

13.1 After the bulk specific gravity of the test specimens has been determined, the stability and flow tests are performed as follows:

13.1.1 Place an old briquet in the 140°F water bath for five minutes. Place it in the breaking head and center breaking head in the loading device. Warm the Marshall Proving Ring by flexing it three times from 0.100 to 0.200 inches (approximately two complete revolutions of the dial).

Note 5 - Not all Marshall machines have proving rings.

13.1.2 The flowmeter gage shall be adjusted to zero when placed in position on the breaking head when each individual test specimen is inserted between the breaking head segments. Graduations of the flowmeter gage shall be in 0.01 in. (0.25 mm) divisions.

13.1.3 Immerse specimen in water bath at 140 ± 1.8°F for 30 to 40 minutes.

13.1.4 Thoroughly clean inside surfaces of testing head. Lubricate guide rods with a thin film of oil so that the upper test head will slide freely.

13.1.5 With testing apparatus in readiness, remove test specimen from water bath and carefully dry surface. Place specimen in lower testing head and center, then fit the upper testing head into position and center complete assembly in the loading device. Place flowmeter over guide rod.

13.1.6 Apply testing load to specimen at constant rate of deformation of 2 inches per minute, until failure occurs. The point of failure is defined as the maximum load obtained. The total number of pounds required to produce failure of the specimen at 140°F shall be recorded as the Marshall stability value.

13.1.7 While stability test is in progress, hold the flowmeter firmly in position over the guide rod and remove as soon as the load begins to decrease; take the reading and record. This reading is the flow value of the specimen, expressed in units of 1/100 inch. For example, if the specimen deformed 0.15 inches, the flow value is 15.

13.1.8 The entire procedure, both stability and flow tests, starting with the removal of the specimen from the water bath, shall be completed within a period of thirty seconds.

14 Density and Voids Analysis:

14.1 After the completion of the stability and flow tests, density and voids analysis is made for each series of test specimens as follows:

14 Density and Voids Analysis: (continued)

14.1.1 Average the bulk specific gravity values for all test specimens of a given asphalt content. Values obviously in error shall not be included in the average.

14.2 Obtain the maximum specific gravity of each mixture. For the purpose of these calculations, the maximum mixture specific gravity (Gcm) may be determined by:

14.2.1 MT-321, the Rice Method, which is an actual measurement of the maximum mixture specific gravity,

14.2.2 The following alternate method which provides a theoretical value for maximum mixture specific gravity [aggregate bulk saturated-surface-dry (SSD) specific gravity basis]. The value obtained by the bulk specific SSD gravity method will usually be lower than the actual measurement obtained with the Rice Method, possibly as much as two percent. This should be taken into account when considering using this method for calculation of maximum mixture specific gravity.

$$G_{cm} = \frac{p_1 + p_2 + p_3 + p_4}{\frac{p_1}{g_1} + \frac{p_2}{g_2} + \frac{p_3}{g_3} + \frac{p_4}{g_4}}$$

where:

G_{cm} = maximum theoretical specific gravity of mixture (void less, aggregate bulk SSD specific gravity basis).

p_1, p_2, p_3, and p_4 = percent by weight of coarse aggregate, fine aggregate, mineral filler and bituminous material, respectively. These percentages are based on total weight of mix and their sum should equal 100%.

g_1 and g_2 = bulk SSD specific gravity of coarse and fine aggregate.

g_3 = bulk or apparent specific gravity of mineral filler or chemical additive.

g_4 = specific gravity of bituminous material.

example: p_1 = 43.9, p_2 = 48.6, p_3 = 1.5, p_4 = 6.0

g_1 = 2.683, g_2 = 2.635, g_3 = 2.404, g_4 = 1.028

$$G_{cm} = \frac{43.9 + 48.6 + 1.5 + 6.0}{\frac{43.9}{2.683} + \frac{48.6}{2.635} + \frac{1.5}{2.404} + \frac{6.0}{1.028}}$$

$$G_{cm} = \frac{100}{16.36 + 18.44 + 0.62 + 5.84} = \frac{100}{41.26} = 2.424$$

14.3 The percentage of air voids by volume is calculated for each specimen and is determined by use of the following equation:

$$V_V = \frac{G_{cm} - G_{mb}}{G_{cm}} x100$$

where:

V_v = volume of air voids as percent of the bulk volume of specimen.

14 Density and Voids Analysis: (continued)

G_{cm} = calculated maximum theoretical specific gravity of mixture or measured (Rice) maximum mixture specific gravity.

G_{mb} = measured bulk specific gravity of compacted mixture.

INTERPRETATION OF TEST DATA

15 Preparation of Data:

15.1 The stability, flow values, and air void data are prepared as follows:

15.1.1 Measured stability values for specimens that depart from the standard 2.5 .05 inch value are corrected by means of a Correlation Ratio. Correlation Ratios used to convert the measured stability values are set forth in Table I.

TABLE I - STABILITY CORRELATION RATIOS

Specimen Vol., cc.	Approx. Specimen Thickness in inches	Correlation Ratio	Specimen Vol., cc.	Approx. Specimen Thickness In inches	Correlation Ratio
200-213 . . .	1 . .	5.56 . .	406-420 . .	2 . .	1.47
214-225 . . .	1-1/16 . .	5.00 . .	421-431 . .	2-1/16 . .	1.39
226-237 . . .	1-1/8 . .	4.55 . .	432-443 . .	2-1/8 . .	1.32
238-250 . . .	1-3/16 . .	4.17 . .	444-456 . .	2-3/16 . .	1.25
251-264 . . .	1-1/4 . .	3.85 . .	457-470 . .	2-1/4 . .	1.19
265-276 . . .	1-5/16 . .	3.57 . .	471-482 . .	2-5/16 . .	1.14
277-289 . . .	1-3/8 . .	3.33 . .	483-495 . .	2-3/8 . .	1.09
290-301 . . .	1-7/16 . .	3.03 . .	496-508 . .	2-7/16 . .	1.04
302-316 . . .	1-1/2 . .	2.78 . .	509-522 . .	2-1/2 . .	1.00
317-328 . . .	1-9/16 . .	2.50 . .	523-535 . .	2-9/16 . .	0.96
329-340 . . .	1-5/8 . .	2.27 . .	536-546 . .	2-5/8 . .	0.93
341-353 . . .	1-11/16. .	2.08 . .	547-559 . .	2-11/16. .	0.89
354-367 . . .	1-3/4 . .	1.92 . .	560-573 . .	2-3/4 . .	0.86
368-379 . . .	1-13/16. .	1.79 . .	574-585 . .	2-13/16. .	0.83
380-392 . . .	1-7/8 . .	1.67 . .	586-598 . .	2-7/8 . .	0.81
393-405 . . .	1-15/16. .	1.56 . .	599-610 . .	2-15/16. .	0.78
			611-625 . .	3 . .	0.76

Note 6 - The measured stability of a specimen multiplied by the Correlation Ratio, corresponding to the volume of the specimen and found in Table I, equals the corrected stability for a standard 2.5 ⅟ .05 inch specimen. The volume of the specimen used to find the Correlation Ratio is equal to (B-C) as in paragraph 12.C.

Note 7 - Volume-thickness relationship is based on a specimen diameter of 4 inches.

15.2 Average the flow values, the converted stability values, the bulk specific gravity values and the percent air voids for all specimens of a given asphalt content. Prepare a graphical plot for the following values as illustrated in Fig. 1. (In each graphical plot, connect the plotted values with a smooth curve that obtains the "best fit" for all values.)

15 Preparation of Data: (continued)

15.2.1 Stability vs. Asphalt Content

15.2.2 Flow vs. Asphalt Content

15.2.3 Percent Air Voids vs. Asphalt Content

15.2.4 Bulk Specific Gravity vs. Asphalt Content

16 Trends and Relations of Test Data:

16.1 The test property curves, as plotted in Figure 1, have been found to follow a reasonably consistent pattern for dense-graded asphalt paving mixtures. Trends generally noted are outlined as follows:

16.1.1 The stability increases with increasing asphalt content up to a maximum after which the stability decreases.

16.1.2 The flow value increases with increasing asphalt content. It generally increases quite rapidly after the point where the maximum stability has been reached.

16.1.3 The percentage of air voids in the compacted mixture decreases to a minimum value with increasing asphalt contents. The minimum aggregate value, for the most part, represents the air voids within the mineral aggregate particles. When this minimum value is attained, the air voids between the particles are essentially filled and further increases in asphalt content tend to decrease the stability and increase the flow to a marked degree. The bulk specific gravity also decreases after this point, since the specimen is being increased in volume with the lower specific gravity asphaltic constituent.

17 Determination of Optimum Asphalt:

17.1 The optimum asphalt content of the asphalt paving mix is determined from data obtained as outlined above. Consideration is given to the four test properties illustrated in Figure 1:

17.1.1 Stability

17.1.2 Bulk Specific Gravity

17.1.3 Limit for Air Voids (limits shown in Table II)

17.1.4 Flow

17.2 The optimum asphalt content of the mix is the median of the limits for air voids unless the other values are unacceptable at this percent of air voids. This should result in a satisfactory paving mix with relatively non- absorptive, well-graded, angular aggregates. Where unusual aggregates must be used, their unusual properties must be recognized, and adjustments made in the application of the criteria to obtain the best possible paving mixture. A discussion on possibilities follows:

17.2.1 Highly absorptive aggregates will produce mixtures with high air void contents. It may not even be possible to come within the air void range without violating satisfactory stability or flow requirements. (Note 8)

Note 8 - Using bulk specific gravities of absorptive aggregates in voids determinations assumes that there is no asphalt absorption and all voids are between the aggregate pieces. By using apparent specific gravities, the assumption is made that the aggregate absorbs all the asphalt it is capable of absorbing and all interior voids are filled. Neither assumption is correct for absorptive aggregates

17 Determination of Optimum Asphalt: (continued)

as the actual absorption is dependent upon asphalt viscosity, size of interior pores, surface tension, temperature and time. It is recommended that air voids always be determined by use of the maximum (Rice) mixture specific gravity when absorptive aggregates are involved.

17.2.2 Some good quality, well graded and very angular aggregates will develop stabilities which are greatly in excess of requirements for a satisfactory pavement. If the stability is 2500 pounds or over, there is no advantage in gaining more stability if an adjustment in the asphalt content will benefit the other criteria. An abnormally high stability mixture may have an abnormally low flow value, which would indicate a brittle mixture. In this instance, the better paving mixture would be obtained by increasing the flow (above 8), and perhaps losing some stability. This would be accomplished by increasing the asphalt content.

TABLE II
DESIRABLE RANGES OF TEST PROPERTIES
FOR MARSHALL DESIGN CRITERIA (Note 10)

Test Property	Grade A		Grade B		Grade C		Grade D		Base	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max
Stability, lbs.	1500	---	1500	---	1000	---	1500	---	750	---
Flow	8	16	8	16	8	18	8	16	8	16
Air Voids in Compacted Mix	4	7	3	5	3	6	3	5	3	8

Note 9 - For a project under the rutting specification, the Marshall design criteria shall be as follows: sufficient stability in the laboratory so that 1500 pounds of stability can be obtained in the field within a void range of 2 to 5 percent.

18 Determination of Optimum Gradation:

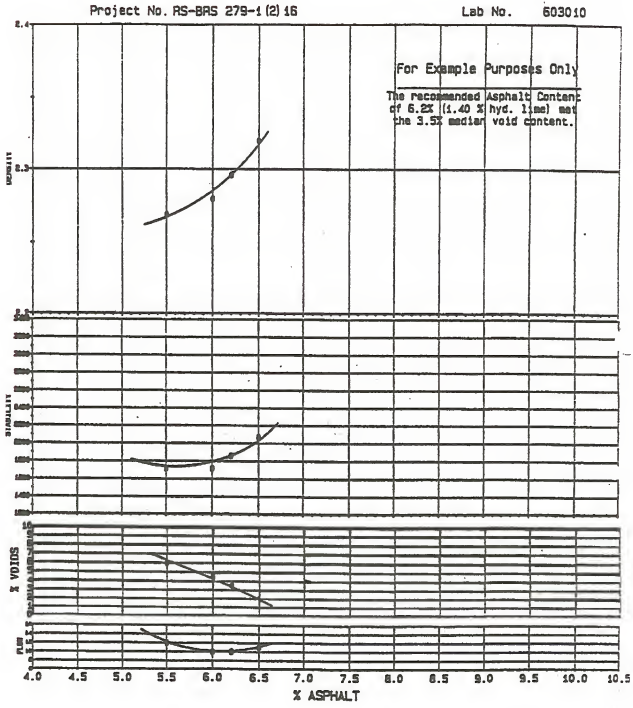
18.1 The contractor makes a determination of the grading he will use based on his stockpile gradations and the most efficient utilization of aggregate. Normally when applicable specification requirements are met by the aggregate, the contractor uses the average gradation of the stockpile. If not, he sets the target gradations within specifications to best match his stockpile quantities and gradations. In some cases the contractor may have to reject fines, etc. In any case the contractor tries to obtain the most efficient and economical utilization of the materials available.

18.2 The target gradings or job mix formula, as determined in 18.1.), are used when testing for the optimum asphalt content.

19 Reporting Results:

19.1 Figure 1 is an example of processing data by means of graphical plots referred to in paragraph 15.2.

19.2 Figure 2 is an example of a completed report form on which test results are recorded.


Project No. RS-BRS 279-1(2)16
Lab No. 603010
For Example Purposes Only
The recommended Asphalt Content of 6.2% (1.40 % hyd. lime) met the 3.5% median void content.
% VOIDS
% ASPHALT
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
10.5

Revised 08/99

ADT
ADT
ESALS

MONTANA
DEPARTMENT OF TRANSPORTATION
Materials Bureau

PLANT MIX SURFACING, GRADE D

Lab. No. 775599 Sample No. 1 Project No. HWY- #305706-RR
Termini East Glacier - West
Date Sampled 8-25-99 Date Received 8-30-99
Sampled by D. Wollan Title MTC Supt. Address Shelby, Mt.
Submitted by James Blossom Title DMS Address
Area Source Represented by Lab. No. 658357-375 Sample taken at
Owner Roy Doore Jr. Address Browning, Mt.

TEST RESULTS ON AGGREGATE

	% Passing As Tested
1-½"	
1"	
¾"	100
½"	82
⅜"	68
4M	48
10M	32
40M	15
200M	6.5

LL NP
PL NP
PI NP
SE 38
Wear 19

Fracture 1 face 88
2 face 79
Dust
Asphalt Ratio 1.16

Volume Swell

NO	3.0	% Hard
HL	2.3	% Hard
CF	2.7	% Hard
NF		%

Absorption CS 1.107 Fine 2.585 Blend 1.337

Bulk Dry Sp. Gr. of Agg. Fine 2.565 CS 2.616

NOTE: VMA of this Mix Design 14.2 VFA 78.2

MARSHALL TESTS

%	Type	Asphalt	Rice Gravity	Unit Weight Lbs./Ft.³	% Voids	Lb. Stability	Flow (in.)	Appearance
1.4	HL	4.5	2.484	144.6	6.7	3232	13	Normal
1.4	HL	5.0	2.463	145.8	5.2	3064	13	Normal
1.4	HL	5.5	2.443	147.1	3.5	2910	14	Sltly Rich
1.4	HL	6.0	2.422	147.7	2.3	2614	15	Sltly Rich
1.4	HL	6.5	2.402	147.9	1.3	2434	17	Rich
1.4	HL	5.6	2.439	147.3	3.1	2820	14	Interplted

MODIFIED LOTTMAN

%	Mineral Filler Type	Percent Asphalt	Grabs (PSI) Dry	Grabs (PSI) Wet	Retained Strength	Adhesion
----	None	5.9			%	80%
1.4	Hyd.Lime	5.7			%	85%

1 Admin. Maintenance Div.
District Admin./Eng. Great Falls
1 District Const. Eng. Great Falls
1 Project Manager Great Falls
1 Dist. Mat. Supr. Great Falls
Area Lab
1 Chief Const. Bureau
Chief Materials Bureau
Bit. Mix Design Sect.
FHWA
Materials Bureau File
1 BIANNZK COAST.

Recommended: 5.6 % Pr 64-22 A/C 1.4 % Hyd. Lime

REMARKS: Discussed with R.D.T. Asphalt Supplier MRC

[signature] 9/6/99
Date Name

April 1, 2000

12 of 12

METHODS OF SAMPLING AND TESTING
MT 307-04
METHOD OF TEST FOR CENTRIFUGE EXTRACTION OF BITUMINOUS MIXES
(Modified AASHTO T164 Method A)

1 Scope:

1.1 This method of test is used for quantitative determinations of bitumen in hot-mixed paving mixtures and pavement samples for specification acceptance, service evaluation, control and research.

2 Apparatus:

2.1 *Extraction Apparatus* - consisting of a bowl approximating that show in Fig. 1 and an apparatus in which the bowl may be revolved at controlled variable speeds up to 3600 rpm. The speed may be controlled manually or with a preset speed control. The apparatus should be provided with a container for catching the solvent thrown from the bowl and a drain for removing the solvent. The apparatus preferably shall be provided with explosion-proof features and installed in a hood or an effective surface exhaust system to provide ventilation.

NOTE 1 - Similar apparatus of larger size may be used.

2.2 *Filter Rings* - felt or paper, to fit the rim of the bowl.

2.3 *Oven* - capable of maintaining the temperature at 230 ± 9°F (110 ± 5°C).

2.4 *Pan* - flat, of appropriate size to warm test specimens.

2.5 *Balance or scale* - with weights shall have a sensitivity of 0.1 grams.

2.6 *Hot Plate* - electric, with adjustable heating rate.

2.7 *Cylinders* - Graduated, 1000 or 2000 ml capacity. Optional cylinder, 100 ml capacity.

3 Reagent:

3.1 *Methylene Chloride* - technical grade.

3.2 *1,1,1-Trichloroethane* - conforming to Federal Specification O-T-620a (Int. Amd.3).

3.3 *Trichloroethylene* - reagent grade (Note 3) or technical grade Type 1, Federal Specification O-T-634, latest revision.

NOTE 2 - Reagent grade Trichloroethylene may be required when asphalt is recovered from the solution.

4 Precautions:

4.1 The solvent should be used only under a hood or with an effective surface exhaust system in a well-ventilated area.

4.2 Trichloroethylene in the presence of heat and moisture may form acids that are extremely corrosive to certain metals, particularly when subject to contact over lengthy periods of time. Proper precautions should be taken to not allow this solvent to remain in small quantities in the effluent tanks of aluminum vacuum extractors.

4 Precautions: (continued)

4.3 Trichloroethylene when stored in a steel container and in continuous contact with moisture may decompose by dehydrohalogenation to form unsaturated hydrocarbon liquids and hydrogen chloride. Steel drums containing trichloroethylene should be stored in a cool dry location, kept tightly sealed and opened as infrequently as possible. Trichloroethylene should be transferred from the drums to clean, dry brown glass bottles for laboratory use. The hydrogen chloride in decomposed trichloroethylene may harden an asphalt during the extraction test.

5 Sampling:

5.1 If the mixture is not sufficiently soft to separate with a spatula or trowel, place it in a large, flat pan and warm to 230±9°F (110±5°C) only until it can be handled or mixed. Split or quarter the material until the mass of material required for test is obtained.

5.3 The size of the test shall be governed by the nominal maximum aggregate size in the mixture and conform to the mass requirement shown in Table 1 (Note 3):

Table 1 Size of Sample

Nominal Maximum Aggregate Size Standard Alternate Mm		Minimum Mass Of Sample Kg
4.75	(No.4)	0.5
9.5	3/8 in.	1
12.5	1/2 in.	1.5
19.0	3/4 in.	2
25.0	1 in.	3
37.5	1½ in.	4

NOTE 3 - When the mass of the test specimen exceeds the capacity of the equipment used (for a particular method), the test specimen may be divided into suitable increments, tested, and the results appropriately combined for calculation of bitumen content.

6 Procedure:

6.1 Determine the moisture content of the material in accordance with Section 5.

6.2 Place the test portion into a bowl.

6.3 Cover the test portion in the bowl with trichloroethylene, and allow sufficient time for the solvent to disintegrate the test portion (not over ½ hr.). Place the bowl containing the test portion and the solvent in the extraction apparatus. Dry and determine the mass of the filter ring and fit it around the edge of bowl. Clamp the cover on the bowl tightly and place a beaker under the drain to collect the extract.

6.4 Start the centrifuge revolving slowly and gradually increase the speed to a maximum of 3600 rpm until solvent ceases to flow from the drain. Allow the machine to stop, add 200 ml (or more as appropriate for mass of sample) trichloroethylene, and repeat the procedure, Use the sufficient solvent additions (not less than three) so that the extract is not darker than a light straw color. Collect the extract and the washings in an appropriate container for mineral matter determination.

6.5 Remove the filter ring from the bowl and dry in air. If felt filter rings are used, brush off mineral matter adhering to the surface of the ring and add to the extracted aggregate. Dry ring to constant mass in an over at 230 ± 9°F degrees (110 ± 5°C). Carefully remove all the contents of

6 **Procedure:** (continued)

the bowl into a metal pan and dry on a steam bath and then to constant mass in an oven or on a hot plate at 230 ± 9°F(110 ± 5°C). If trichloroethylene or trichloroethane is used as the extraction solvent, the preliminary drying on a steam bath may be omitted. The mass of the extracted aggregate (W_3) is equal to the mass of the aggregate in the pan plus the increase in mass of the filter rings.

6.6 Determine the amount of material matter in the extract – For this method, any suitable (700 g or higher) centrifuge may be used.

6.7 After extracting, place solvent-bitumen mixture into centrifuge starting centrifuge slowly. Gradually increase speed to 700 g or higher for thirty (30) minutes. Remove solvent from centrifuge and discard.

6.8 Air-dry the bottles, remove fine material. Weigh material and add to weight of extracted aggregate.

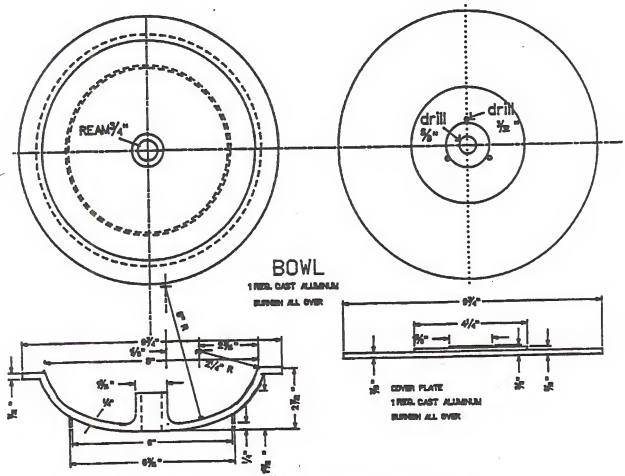


Fig. 1.-Extraction Unit Bowl

Centrifuge Extraction Worksheet

Lab No. _____ Sample No. _____ Project No. _____

Project Designation _____

Before Extraction

A _____ Weight of Sample

B _____ Weight of Pan

C _____ Weight of Filter

D _____ Weight of Filter and Pan

After Extraction

E _____ Weight of Sample, Pan and Filter

E _____ - D _____ = F _____ Wt. after Extraction

A _____ - F _____ = G _____ Wt. of Asphalt

G/A _____ = H _____ Percent of Asphalt by Total Mix

Weight if Filter after Extraction _____

Filter Gain _____

Before Wash _____ After Wash _____ LBW _____

Wt. Ret.	Wt. Pass	Pct.
_____	1"	_____
_____	¾"	_____
_____	½"	_____
_____	3/8"	_____
_____	4M	_____
_____	10M	_____
_____	40M	_____
_____	200M	_____

Fracture _____

METHODS OF SAMPLING AND TESTING
MT 308-04
TEMPERATURE-VISCOSITY CHARTS FOR USE IN DETERMINING MIXING TEMPERATURES FOR THE VARIOUS GRADES OF ASPHALT CEMENT
(Montana Method)

1. Scope:

1.1 Temperature-Viscosity data for the various grades of bituminous materials used in Montana are listed in Tables I and II.

2. Contractor Responsibility:

2.1 The contractor will furnish the Project Engineer with data on the temperature-viscosity relationship of each asphalt to be used on the project. The data must cover the recommended temperature range and viscosities at which the asphalt will be used. The Project Manager will use this data to specify the temperature at which the material will be used.

Note - The contractor will furnish the most recent copy of the temperature-viscosity chart available at the time the material is purchased in order to ensure the greatest accuracy.

3. Temperature - Viscosity Data:

3.1 An example temperature-viscosity chart is included to illustrate a temperature-viscosity chart used for Materials Bureau design purposes. Temperature-viscosity charts are updated periodically to monitor any changes in temperature-viscosity that may occur.

Note - Asphalt cements (PG grade) for plant mix surfacing contracts have temperature-viscosity requirements issued by the Materials Bureau in the Mix Design memorandum, which govern the contract.

3.2 An example form is included to illustrate the documentation of the values that are recommended for mix design and field operations for the contractor and by the asphalt supplier for Polymer Modified Asphalt.

TABLE I

TEMPERATURE VISCOSITY DATA FOR DIFFERENT GRADES OF ASPHALT CEMENT

Mixing Range (150-190 Centistokes)

CENEX

PG 64-22	310-320°F
PG 64-34	297-311°F
PG 70-28	319-335°F

CONTINENTAL OIL COMPANY

85/100	285-294°F
120/150	277-285°F
200/300	267-276°F

EXXON/MOBIL COMPANY

PG 58-28	144-149°F
PG 64-22	----------°F
PG 64-28	----------°F
PG 64-34	150-165°F
PG 70-28	155-165°F

MONTANA REFINING COMPANY

85/100	290-301°F
120/150	285-297°F
200/300	271-280°F

TABLE II

TEMPERATURE VISCOSITY DATA FOR DIFFERENT GRADES OF LIQUID ASPHALT FROM MONTANA REFINERIES

Spraying Range 25-100 S.F. Sec. (50-200 Centistokes)

MONTANA REFINING COMPANY

MC-70	111-160°F	SC-70	110-172°F
MC-250	155-212°F	SC-250	160-215°F
MC-800	198-260°F	SC-800	192-255°F
MC-3000	225-287°F	SC-3000	222-285°F

CENEX

MC, & SC-70	105-175°F
MC, & SC-250	147-225°F
MC, & SC-800	181-256°F
MC, & SC-3000	214-290°F

CONTINENTAL OIL COMPANY

MC-70	112-165°F
MC-250	158-215°F
MC-800	200-265°F
MC-3000	227-290°F

TABLE I

TEMPERATURE VISCOSITY DATA FOR DIFFERENT GRADES OF ASPHALT CEMENT

Mixing Range (150-190 Centistokes)

IDAHO ASPHALT

PG 64-22	310-325°F
PG 64-28	310-330°F
PG 64-34	320-330°F
PG 70-28	320-340°F

KOCH

PG 64-34	300-316°F

MOOSE JAW ASPHALT

PG 58-28	292-299°F
PG 64-34	325°338°F

MONTANA REFINING COMPANY

PG 58-28	293-304°F
PG 64-28	295-340°F
PG 70-28-	275-350°F

TABLE II

TEMPERATURE VISCOSITY DATA FOR DIFFERENT GRADES OF LIQUID ASPHALT FROM MONTANA REFINERIES

Spraying Range 25-100 S.F. Sec. (50-200 Centistokes)

MONTANA REFINING COMPANY

MC-70	111-160°F	SC-70	110-172°F
MC-250	155-212°F	SC-250	160-215°F
MC-800	198-260°F	SC-800	192-255°F
MC-3000	225-287°F	SC-3000	222-285°F

CENEX

MC, & SC-70	105-175°F
MC, & SC-250	147-225°F
MC, & SC-800	181-256°F
MC, & SC-3000	214-290°F

CONTINENTAL OIL COMPANY

MC-70	112-165°F
MC-250	158-215°F
MC-800	200-265°F
MC-3000	227-290°F

NOTE: Exxon Company no longer produces cutback asphalts, thus temperature viscosity data for the Exxon Company is no longer listed in Table II. In addition, Montana Refining Company no longer produces rapid cure (RC) cutback asphalts and thus no RC data for them is provided. Continental Oil no longer produces slow cure (SC) or rapid cure (RC) cutback asphalts and no data for them is provided.

(FOR EXAMPLE ONLY)

As a supplier of polymer modified asphalt for a Montana Department of Transportation project, we request that you provide the following information to the Materials Bureau. A completed form is required for each variety of Polymer asphalt submitted and for each project from which polymer asphalt will be supplied.

Project
Termini

(1) Safety Data Sheets

(2) Temperature-viscosity chart and/or table for viscosity from 275 degrees F. To 340 degrees F. Or to the maximum mixing temperature of the asphalt.

(3) Mix Design Temperature Ranges

a. Mixing viscosity range 290°F - 310°F

b. Compaction Viscosity Range 230°F - 290°F

(4) Field Temperatures (plant mix operational temperatures)
That is the temperature maximum 310°F degrees F.
and the temperature minimum 290°F degrees F. of plant mix as it is discharged from the plant.

a. Maximum temperature at which roadway compaction may be performed 290°F

b. Minimum temperature at which roadway compaction may be performed 230°F

Company providing modified asphalt Montana Refining Company

Individual providing information Alan Hobbs

Address P.O. Box 1243, Great Falls, MT 59403

Phone No. (406)761-4100

Completion of this form provides the documentation of the values that are recommended for mix design and field operations for the contractor and by the asphalt supplier.

Identification of modified asphalt _____

Signature _____ Date _____

METHODS OF SAMPLING AND TESTING
MT 309-04
METHOD OF TEST FOR
REDUCING SAMPLES OF HOT MIX ASPHALT TO TESTING SIZE
(Modified WAQTC TM 5)

1 Scope:

1. This method covers the procedure for reducing samples of Hot Mix Asphalt (HMA). The samples are to be taken according to MT-303 and the increments placed in an agency approved container. The sample is to be representative of the average of the HMA being produced. The field sample when reduced once should yield a sample of sufficient mass that a quarter of the field sample will meet the testing requirements. The initial reduction of the field sample should be accomplished as close as possible to the point of sampling, to avoid excessive cooling of the sample. The further reduction to test size may be done at this time or at another time and location as necessary.

2 Referenced Documents:

2.1 *MT Manual:*
MT-303 Sampling Bituminous Paving Mixtures

WAQTC:
TM 5

3 Apparatus:

3.1 *Oven* – The oven shall be capable of maintaining compaction temperature range.

2.2 *Splitting Surface* – A non-stick surface such as metal, paper, canvas blanket or heat-resistant plastic.

2.3 *Miscellaneous equipment* – Flat-bottomed scoop, broom or brush, large spatulas, trowels, metal straight edge or 12 in. dry wall taping knife, sheet metal quartering splitter, hot plate, heat resistant gloves or mittens, pans, buckets and cans.

3 Sample Preparation:

3.1 The sample must be warm enough to separate. If not, warm in an oven until it is sufficiently soft to mix and separate easily.

4 Procedure:

4.1 *Initial Reduction of Large Field Samples:*

4.1.1 Heat the trowel(s), spatula(s), and splitting apparatus to approximately 110ºC (230ºF).

4.1.2 Place the sample on a hard, clean, non-stick, level surface where there will be neither loss of material nor the accidental addition of foreign material. The surface may be covered with a canvas blanket, heavy paper or other suitable material. Remove the sample from the agency approved container by dumping into a conical pile.

4.1.3 Mix the material thoroughly by turning the entire sample over four times. With the last turning, form the entire sample into a conical pile.

Note 1 – Mixing may be accomplished by turning the pile with a heated spatula or by rolling the material over with paper or other material used for the rolling surface. To minimize segregation with lean mixes or mixes with aggregate larger than ¾" (19mm), re-mixing the sample is not recommended.

4 Procedure: (continued)

4.1.4 Flatten the conical pile to a uniform thickness and diameter by pressing down with a hot spatula or trowel. The diameter should be four to eight times the thickness.

4.1.5 Divide the flattened pile into four approximately equal quarters with a heated spatula, trowel, flat metal plate, or sheet metal quartering splitter.

4.1.6 With the quartering device in place remove all the material from each quarter. If needed for additional testing the material should be placed in an agency approved container for storage for shipment.

Note 2 – Pay particular attention that excessive amounts of material is not left on the splitting surface or splitting equipment.

4.1.7 When the further reduction of the HMA is to be done at this time discard all material residue from the other quarters and proceed according to Sec. 5.2.

5 Reducing Samples to Test Size:

5.1 On a hard, clean, non-stick, level surface where there will be neither loss of material nor the accidental addition of foreign material, cover the surface with either a canvas blanket, heavy paper, or other suitable material. Remove the sample from the container by dumping into a conical pile.

5.2 Mix the sample thoroughly by turning the entire sample over four times. Alternately lift each corner of the canvas or paper and pull it over the sample diagonally toward the opposite corner causing the material to be rolled. With the last turning, lift both opposite corners to for a conical pile.

5.3 Flatten the conical pile to a uniform thickness and diameter by pressing down with a hot spatula or trowel. The diameter should be four to eight times the thickness.

5.4 Quarter the material using a quartering device or straightedge.

5.5 With the quartering device in place, using a straightedge (taping knife), slice through the quarter of the HMA from the apex of the quarter to the outer edge. Pull or drag the material from the quarter holding one edge of the straightedge (taping knife) in contact with the quartering device. Two straightedges may be used in lieu of the quartering device.

5.6 Slide or scoop the material into a sample pan. Repeat step 5.5 removing a similar amount of material from the opposite corner and repeat until all the samples for testing have been obtained.

Note 3 – When reducing the sample to test size it is advisable to take several small increments determining the mass each time until the proper minimum size is achieved. Unless the sample size is grossly in excess of the minimum or exceeds the maximum test size use the sample as reduced for the test.

METHODS OF SAMPLING AND TESTING
MT 310-04
THE DETERMINATION OF BITUMINOUS AGGREGATE TREATMENTS

1 Scope:

1.1 This method is intended as a guide for standard aggregates for determining bituminous special treatments of sub-mixtures, which will improve their quality to a satisfactory level for the use intended.

1.2 A treatment may consist of processing modification, a materials addition, or an additional process that may involve the addition or subtraction or modification of materials components. Specific treatments to be evaluated may include but are not necessarily confined to the following:

1.2.1 Addition of an aggregate fraction.

1.2.2 Rejection of a portion of an aggregate fraction.

1.2.3 Rejection of a portion of, or all of, an aggregate fraction, and replacing with more satisfactory material.

1.2.4 Addition of a mineral filler.

1.2.5 Addition of hydrated lime.

1.2.6 Addition of hydrated lime with a moisture cure.

1.2.7 Addition of an asphalt adhesive agent.

1.2.8 Washing of the aggregate.

2 Referenced Documents:

2.1 ***MT Materials Manual:***
MT-209 – Los Angeles Abrasion (wear test) (Modified AASHTO T 96)
MT-227 – Determination of Degradation Value (State of Wash. Method)
MT-305 – Volume Swell of Bituminous Mixtures (Montana Method)
MT-306 – Marshall Method of Bituminous Mix Design (Modified AASHTO T 245).
MT-324 – Effect of Water on Cohesion of Compacted Bituminous Mixtures (AASHTO T 165).

3 Evaluation Procedure:

3.1 Determination of the need for, and evaluation of treatments will be made by following the flow chart shown on page 3 of this procedure.

3.2 Following the flow chart will resolve questions concerning the need for improving the quality of sub-standard aggregates in all usual circumstances. There are some known conditions and others may become apparent which represent situations which should be excluded from this method. These situations will be resolved as they occur by special laboratory and field investigations, by performance records, experience in the area, or other applicable engineering judgments.

3.3 Except as noted in 3.B., a treatment shall be deemed ineffective and shall not be used if it does not accomplish one of the following:

3.3.1 Increase the Retained Strength by at least 15 percentage points.

3 **Evaluation Procedure:** (continued)

3.3.2 Increase the Marshall Stability 250 lbs.

3.3.3. Increase Adhesion by at least 25 percentage points.

3.3.4 Decrease Volume Swell by at least 3.5 percentage points.

4 **Application:**

4.1 The most economical treatment that provides the desired improvement in test results will ordinarily be the one designated for use.

4.2 This method may not be applicable for situations where standard quality materials may not be required to the extent that it justifies treatment costs. Examples are temporary and short-term designed pavements and road mixes.

4.3 There may be other situations where a superior product is required and more than the minimally effective treatment is justifiable. Very high and heavily loaded traffic areas and specially designed wearing course overlays may be in this category.

4.4 Necessary treatments that can be determined with a sufficient degree of certainty during planning and pre-construction stages will be provided for in the contract provisions. Further confirmation testing will be done in the aggregate production stage and final monitor testing will be done on the produced Bituminous-Aggregate mixtures. The final judgment concerning treatments will be made on the monitor tests of pavement materials in the condition, which exists when they are placed on the roadway.

METHODS OF SAMPLING AND TESTING
MT 311-04
MARSHALL METHOD FOR FIELD CONTROL OF HOT MIX ASPHALT PAVING
(Montana Test Method)

1 Scope:

1.1 This method of test is to be used for specifying, obtaining, and maintaining the best possible physical or structural properties of asphalt hot mix paving.

1.2 The method is applicable to hot mix asphalt paving mixtures using penetration grades of asphalt cement and containing aggregates with maximum sizes of 25.4 mm (one inch).

2 Compaction Equipment:

2.1 *Compaction pedestal* - consisting of a 203.2 x 203.2 x 457.2 mm (8 inch x 18 inch) wooden post capped by a 304.8 x 304.8 x 25.4 mm (12 inch x 12 inch x 1 inch) steel plate. The post should be placed on a 609.6 x 609.6 x 101.6 mm (24 inch x 24 inch x 4 inch) concrete block so it is plumb, the top is level and the entire assembly is free from movement during use. Double or triple hammer compactors will require an appropriately larger base.

2.1.1 Prior to compaction, a quantity of the bituminous mixture shall be obtained in order to form a pad upon which to place the compaction pedestal or the jack used to support the floor of the test trailer beneath the compaction pedestal.

2.2 *Compaction mold* - consisting of a base plate, forming mold and collar extension. The forming mold shall have an inside diameter of 101.6 mm ± 0.13 mm (4 ± 0.005 inches) and a height of approximately 76.2 mm (3 inches); the base plate and collar are designed to be interchangeable with either end of the forming mold.

2.3 *Compaction hammer* - consisting of a flat, circular, tamping face 98.425 mm (3.875 inches) in diameter and equipped with a 4,536 ± 9 g (10 ± 0.02 lb.) sliding weight constructed to obtain a specified 457.2 mm (18 inch) height of drop.

2.4 *Mold holder* - consisting of a spring tension device designed to hold compaction mold in place on compaction pedestal.

2.5 *Extrusion jack* - or arbor press, for extruding compacted specimens from the mold.

2.6 *Jack* - for supporting floor of test trailer beneath compaction pedestal.

3 Securing Sample:

3.1 Samples of the bituminous paving mixtures shall be obtained in accordance with MT-303.

3.2 The sample should be large enough to provide sufficient material to mold a minimum of two specimens (approximately 1150 gms, each).

3.3 Record on the work sheet the stationing, lift, and lane where the load, representing the sample, was placed.

4 Preparation of the Mold and Hammer:

4.1 Thoroughly clean the specimen mold assembly and the face of the compaction hammer and heat them in boiling water or on the hot plate to a temperature between 93.3 and 148.8°C (200 and 300°F). Place a piece of filter paper or paper toweling, cut to size, in the bottom of the mold before the mixture is placed in the mold.

5 Compaction Temperature:

5.1 Place a thermometer in the sample until the reading stabilizes and record the reading.

5.2 Select the compaction temperature so that the viscosity of the asphalt is 280 ± 30 C_{st}, as obtained by using the temperature viscosity charts in MT-308.

6 Compaction of Specimen:

6.1 Place a sufficient amount of the mixture, at approximately the temperature prescribed in paragraph 5.2 (Note 1) in the mold to produce a compacted briquette approximately 63.5 ± 1.27 mm (2.5 ± 0.05 inches) high. Spade the mixture vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times through the interior. Care should be taken so that an excess of coarse aggregate is not segregated to the surface or the face of the specimen will be rough and have higher voids than the interior of the specimen.

Note 1 - Do not attempt to increase the temperature of the mixture by heating. If mixture is below temperature required, a new sample must be taken.

6.2 Remove the collar and smooth the surface to a slightly rounded shape.

6.3 Replace the collar and place a filter on top of the mixture prior to compaction.

6.4 Place the mold assembly on the compaction pedestal in the mold holder, and, unless otherwise specified, apply 50 or 75 blows with the compaction hammer with a free fall of 457.2 mm (18 inches). Hold the axis of the compaction hammer perpendicular to the base of the mold assembly during compaction.

6.5 Remove the base plate and collar, and reverse and reassemble the mold.

6.6 Apply the same number of compaction blows to the face of the reversed specimen.

6.7 After compaction is completed, air cool the specimen by the use of fans for 30 minutes.

6.8 Remove the specimen from the mold by means of an extrusion jack or other compression device, and place on a smooth, level surface until ready for testing.

6.9 Form a second specimen, as rapidly as possible, in the same manner as described in paragraph 6.1 through 6.8

7 Test Procedure:

7.1 Each finally compacted test specimen is subjected to the following tests and analysis in the order listed:

Bulk Specific gravity Determination
Stability and Flow Test
Density and Voids Analysis

8 Equipment Necessary for Testing Specimens:

8.1 Marshall Testing Machine – An electrically powered testing device, for determining the compressive strength and a Marshall flow meter for determining the maximum strain at the maximum load for test.

8.2 Water Bath – At least 152.4 mm (6 inches) deep and thermostatically controlled to 60 ± 1°C (140 ± 1.8F).

9 Bulk Specific Gravity of a Compacted Bituminous test Specimen:

9.1 The bulk specific gravity of a compacted specimen may be obtained by computing the ratio of its weight in air to its bulk in volume (including both permeable and impermeable voids normal to the material). The bulk volume may ordinarily be determined by weighing the specimen in water, then weighing the saturated surface-dry specimen in air, and calculating the difference. The equipment necessary to conduct this test is as follows:

9.2 *Balance* – A balance having a minimum capacity of 2 kg and sensitive to 0.1 g or less.

9.3 *Wire Basket* – A wire basket constructed to hold the test specimen while it is being weighed while immersed in water.

9.4 *Container* – sufficient to contain specimen with overflow device, for immersing the wire basket in water and maintaining a constant water level.

9.5 *Suspension Apparatus* – for suspending the wire basket from the center of a scale pan of the balance.

9.6 *Cloth Towel* – for blotting excess water from the specimen after weighing in water.

9.7 Weigh the specimen in air on the balance to the nearest 0.1 g and record this weight as "A". Weigh the specimen suspended in the basket and immersed for three to five minutes in a water bath at 25 ± 1°C (77 ± 1.8 °F). Weigh to the nearest 0.1 g and designate this weight as "C". Remove the specimen from the water, surface dry by blotting with a damp towel, weigh the surface-dry specimen in air to the nearest 0.1 g, and designate this weight as "B".

9.8 Calculate the bulk specific gravity of the test specimen as follows:

Bulk Specific Gravity = $\frac{A}{B-C}$

where:

A = weight of specimen in air,

B = weight of saturated surface dry specimen in air, and

C = weight of specimen in water

10 Stability and Flow Equipment:

10.1 *Breaking Head* - consisting of upper and lower cylindrical segments or test heads having an accurately machined radius of curvature of 50.8 mm (2 in.). The lower segment will be mounted on a base having two perpendicular guide rods or posts extending upward. Guide sleeves in the upper segment will position the two segments together without appreciable binding or loose motion on the guide rods.

10.2 *Loading Jack* - consisting of a screw jack mounted in a testing frame to produce a uniform vertical movement of 50.8 mm (2 in.) per minute. An electric motor may be attached to the jacking mechanism.

Note 2 – Instead of the Loading Jack, a mechanical or hydraulic testing machine may be used provided the rate of movement can be maintained at 50.8 mm (2 in.) per minute while the load is applied.

10.3 *Ring Dynamometer Assembly* - of 22.2 KN (5,000 lbf) capacity and sensitive to 44.5 N (10 lbf) up to 4.45 (1,000 lbf) and 111.2 N (25 lbf) between 4.45 and 22.2 KN (1,000 and 5,000 lbf) and equipped with a micrometer dial. The micrometer dial will be graduated in 0.0025 mm (0.0001 in.). Upper and lower ring dynamometer attachments are required for fastening the ring dynamometer to the testing frame and transmitting the load to the breaking head.

Note 3 – Instead of the ring dynamometer assembly, any suitable load measuring device may be used provided the capacity and sensitivity meet the above requirements.

10 Stability and Flow Equipment: (continued)

10.4 *Flowmeter* - consisting of a guide sleeve and gage. The activating pin of the gage shall slide inside the guide sleeve with a slight amount of frictional resistance. The guide sleeve must slide freely over the guide rod of the breaking head. When each individual test specimen is inserted between the breaking head segments, the flowmeter gage will be adjusted to zero when placed in position on the breaking head. Graduations of the flowmeter gage will be 0.25 mm (0.01 in.) divisions.

Note 4 – *Instead of the flowmeter, a micrometer dial or stress-strain recorder graduated in 0.25 mm (0.01 in.) may be used to measure flow.*

11 Stability and Flow Tests:

11.1 Place an old briquette in the 140°F water bath for five minutes. Place it in the breaking head and center breaking head in the loading device. Warm the Marshall Proving Ring by flexing it three times from 2.54 mm to 5.08 mm (0.100 to 0.200 inches) (approximately two complete revolutions of the dial).

11.2 The flowmeter gage shall be adjusted to zero when placed in position on the breaking head when each individual test specimen is inserted between the breaking head segments. Graduations of the flowmeter gage shall be in 0.25 mm (0.01 in.) divisions.

11.3 Immerse specimen in water bath at 60 ± 1°C (140 ± 1.8°F) for 30 to 40 minutes.

11.4 Thoroughly clean inside surfaces of testing head. Lubricate guide rods with a thin film of oil so that the upper test head will slide freely.

11.5 With testing apparatus in position, remove test specimen from water bath and carefully dry surface. Place specimen in lower testing head and center, then fit the upper testing head into position and center complete assembly in the loading device. Place flow meter over guide rod, adjust the flowmeter to zero and hold the sleeve firmly against the upper segment of the breaking head while the test load is being applied.

11.3 Apply testing load to specimen at a constant rate of deformation of 50.8 mm (2 inches) per minute, until failure occurs The point of failure is defined as the maximum load obtained. The total number of pounds required to produce failure of the specimen at 60°C (140°F) shall be recorded as the Marshall stability value.

11.4 While stability test is in progress, hold the flow meter firmly in position over the guide rod and remove as soon as the load begins to decrease; take the reading and record. This reading is the flow value of the specimen, expressed in units of 0.01 inch. For example, if the specimen deformed 0.15 inches, the flow value is 15.

11.5 The entire procedure, both stability and flow tests, starting with removal of the specimen from the water bath, shall be completed within a period of thirty seconds.

12 Density and Voids Analysis for Each Specimen:

12.1 Average the bulk specific gravity values for all test specimens of a given asphalt content. Values obviously in error shall not be included in the average.

12.2 Maximum mixture specific gravity (G_{mm})may be determined by:

12.2.1 MT-321 - the Rice Method, which is an actual measurement of the maximum mixture specific gravity. The Rice Method is the preferred method and shall normally be used. (Rice gravity values will be furnished with each mix design by the materials Bureau and monitored on the project.

12.2.2 If a situation arises where you elect to use the maximum theoretical density in the voids analysis, use the procedure described in MT-306, paragraph 14.2.

12 Density and Voids Analysis for Each Specimen: (continued)

Note 5 - The desirable ranges of test properties for Marshall design criteria is shown in MT-306, Table II.

12.3 The percentage of voids by volume is calculated for each specimen and is determined by use of the following formula:

$$Vv = \frac{Gem - Gmb}{Gem} x100$$

where:

V_v = volume of air voids as percent of the bulk volume of specimen,

G_{em} = (Rice) maximum mixture specific gravity, and

G_{mb} = measured bulk specific gravity of compacted mixture

Note 6 - The measured stability of a specimen multiplied by the Correlation Ratio, corresponding to the volume of the specimen and found in table I, equals the corrected stability for a standard 63.5 ± 1.27 mm (2.5± .05 inch) specimen. The volume of the specimen used to find the Correlation ratio is equal to (B-C) as in paragraph 9.3

Note 7 - Volume-thickness relationship is based on a specific diameter of 4 inches.

Table 1 Stability Correlation Ratios

Volume of Specimen, cm^3	Approximate Thickness of Specimen, in.	mm	Correlation Ratio
200 to 213	1	25.4	5.56
214 to 225	1 1/16	27.0	5.00
226 to 237	1 1/8	28.6	4.55
238 to 250	1 3/16	30.2	4.17
251 to 264	1 ¼	31.8	3.85
265 to 276	1 5/16	33.3	3.57
277 to 289	1 3/8	34.9	3.33
290 to 310	1 7/16	36.5	3.03
302 to 316	1 ½	38.1	2.78
317 to 328	1 9/16	39.7	2.50
329 to 340	1 5/8	41.3	2.27
341 to 353	1 11/16	42.9	2.08
354 to 367	1 ¾	44/4	1.92
368 to 379	1 13/16	46.0	1.79
380 to 392	1 7/8	47/6	1.67
393 to 405	1 15/16	49.2	1.56
406 to 420	2	50.8	1.47
421 to 431	2 1/16	52.4	1.39
432 to 443	2 1/8	54.0	1.32
444 to 456	2 3/16	55.6	1.25
457 to 470	2 ¼	57.2	1.19
471 to 482	2.5/16	58.7	1.14
483 to 495	2 3/8	60.3	1.09
496 to 508	2 7/16	61.9	1.04
509 to 522	2 1/1	63.5	1.00
523 to 535	2 9/16	65.1	0.96
536 to 546	2 5/8	66.7	0.93
547 to 559	2 11/16	68.3	0.89
560 to 573	2 ¾	69.9	0.86
574 to 585	2 13/16	71.4	0.8s
586 to 598	2 7/8	73.0	0.81
599 to 610	2 15/16	74.6	0.78
611 to 625	3	76.2	0.76

METHODS OF SAMPLING AND TESTING
MT 312-04
METHOD OF DETERMINING MOISTURE CONTENT
OF BITUMINOUS MIXTURES
(*Modified WAQTC TM6*)

1 Scope:

1.1 This method covers the determination of the moisture content of bituminous mixtures in accordance with WAQTC TM6.

2 Referenced Documents:

2.1 ***MT Manual:***
MT-303 Sampling Bituminous Paving Mixtures
MT-309 Reducing Samples of Hot Mix Asphalt to Testing Size

WAQTC
TM5 Reducing Samples of Hot Mix Asphalt of Testing Size

3 Apparatus:

3.1 Forced Air, Ventilated, or Convection Oven, or Hot Plate – capable of maintaining compaction temperature range.

3.2 Thermometer – with a temperature range from 50°F to 400°F (10°C to 204.4°C).

3.3 Balance or scale – with a capacity of at least 2 Kg., readable to 0.1 gram.

3.4 Sample container – Not affected by heat and of sufficient size to contain a test sample of at least 1,000-g without danger of spilling.

4 Sample:

4.1 The test sample shall be obtained in accordance with MT-303, and reduced in accordance with MT- 309, WAQTC TM5. The size of the test sample shall be a minimum of 500 g.

5 Procedure:

5.1 Determine and record the mass of the sample container to the nearest 0.1-g.

5.2 Record the temperature of the test sample.

5.3 Place the test sample in the sample container, and determine and record the total mass of the sample container and the test sample to the nearest 0.1-g.

5.4 Calculate the initial, moist mass of the test sample by subtracting the mass of the sample container determined in Sec 5.1 from the total mass of the sample container and the test sample determined in Sec 5.3.

5.5 Dry the test sample to a constant mass in the sample container.

Note 1 - Constant mass shall be defined as the mass at which further drying does not alter the mass by more than 0.1 percent. Set the oven to a minimum of 105 ± 5°C (221 ±9°F). In no case should the Job Mix Formula (JMF) mixing temperature be exceeded. The sample shall be initially dried 90 minutes, and its mass determined at that time and at 30-minute intervals after that until a constant mass is reached.

5.6 Cool the sample container and test sample to approximately the same temperature as determined in Sec 5.2.

5 Procedure: (continued)

5.7 Determine and record the total mass of the sample container and test sample to the nearest 0.1-g.

Note 2 - Do not attempt to remove the test sample from the sample container for the purposes of determining mass.

5.8 Calculate the final, dry mass of the test sample by subtracting the mass of the sample container determined in Sec 5.1 from the total mass of the sample container and the test sample determined in Sec 5.7.

Note 3 - Moisture content and the number of samples in the oven will effect the rate of drying at any given time. Placing wet samples in the oven with nearly dry samples could affect the drying process.

6 Calculations:

6.1 Calculate the moisture content, as a percentage, using the following formula.

Percent of Initial, Moist Mass: $M = \frac{Mi - Mf}{Mi} \times 100$

Where:

M = % Moisture

Mi = initial, moist mass

Mf = final, dry mass

Example: Mi = 541.2g

Mf = 536.0g

Moisture Content = $\frac{541.2g - 536.0g}{541.2g} \times 100 = 0.961$, say 0.96%

7 Report:

7.1 Report the moisture content to 0.01 percent.

METHODS OF SAMPLING AND TESTING
MT 313-04
PROCEDURE FOR COMPARING NUCLEAR GAUGES TO CORE DENSITIES OF BITUMINOUS PAVING MIXTURES

1 Scope:

1.1 This is a mandatory statewide procedure for comparing density determined by the nuclear gauge with the density of a bituminous core for each lift of plant mix.

2 Apparatus:

2.1 *A motor driven core machine* - capable of obtaining a 10.16 cm (4 inch) diameter core the full depth of the bituminous paving mixture.

2.2 *A nuclear density device* - capable of giving results to the 1 kg/m^3 (0.1 lb./ft.^{3}).

2.3 *Hot plate* - capable of obtaining a temperature above the melting point of paraffin. (Conventional hot plate is sufficient.)

2.4 *Balance* - sensitive to 0.5 g or less.

2.5 *Wire basket* - constructed to hold the test specimen while being weighed in water.

2.6 *A container* - with overflow device for immersing the wire basket in water and maintaining a constant water level.

2.7 An apparatus for suspending the wire basket from the center of the scale pan of the balance.

2.8 *Thermometer* - for maintaining the water temperature at 77ºF ± 2F (25ºC ± 1C).

3 Test Procedure:

3.1 A 100 meter (300 foot long) section (the width of the paver) of the bituminous material will be selected. SEVEN to TEN test sites will be selected at random from this 100 meter (300 foot) section. (See MT-416 for random sampling procedure.) The exact test locations will be recorded on a work sheet.

3.2 The statistical stability of the nuclear gauge shall be determined prior to making density comparisons (refer to the manufacturer's recommended procedure or see MT-212).

3.3 Prior to making a gauge-core comparison, a standard count must be taken with the standard count block placed on the material to be tested. (Refer to the manufacturer's recommended procedure.) This standard count must be validated (see MT-212, 3.4.5).

3.4 Sand native to the material being tested will be used for seating. This sand will be minus No. 30 sieve material oven dried to a constant weight. Enough seating sand should be used to fill all the voids between the nuclear gauge and the bituminous mixture. Care must be exercise not to use too much seating sand as excess sand can influence the density readings.

3.5 The procedure for gauge operation will be according to MT-212. Four one-minute tests at 90□ intervals will be taken and the results averaged. After the rotation, check the source rod to ensure it is positively indexed in the backscatter position. The testing pattern will be as illustrated in Fig. 1.

3 **Test Procedure:** (continued)

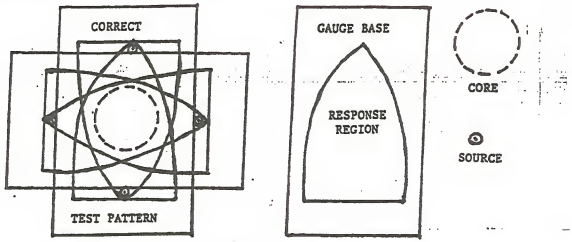


Fig.1

3.6 A bituminous core will be removed from the center of the imprint left by the nuclear gauge as indicated above.

3.7 The bulk specific gravity will be determined according to MT-314 Method A or Method B. Note: If the percent water absorbed by the specimen exceeds 2 percent as calculated in MT-314, Section 7.2 use Method A only. Record the result to 1kg/m^3 (0.1 lb./ft.^{3}).

For determination of the bulk specific gravity of the top lift, the core has to be split on the meet line and the top lift used for determining the bulk specific gravity.

3.8 All information shall be recorded on the work sheets and a copy sent to the Materials Bureau.

3.9 The cores will be retained in the district or area laboratory until completion of the paving project.

4 Computations and Interpretation of Results:

4.1 The correlation is determined as follows:

4.1.1 Average the four nuclear tests at each test site, round to 1 kg/m^3 (0.1 lb./ft.^{3}), and record.

4.1.2 Subtract the nuclear test average from the core density determined at that site and record the difference to 1 kg/m^3 (0.1 lb./ft.^{3}).

4.1.3 Average the differences being careful to include the algebraic sign (+ or -) of each difference. Record to the nearest 1 kg/m^3 (0.1 lb./ft.^{3}).

4.1.4 If the average difference is positive, add that amount to all wet density readings; if the difference is negative, subtract the average difference from all wet density readings. DO NOT ADJUST THE MARSHALL DENSITY. Negative correlations need not be regarded with suspicion unless the gauge density exceeds core density by more than 32 kg/m^3 (2.0 lb./ft.^{3}). Consult the Materials Bureau in this case.

4.2 Example:

A Troxler Model 3411-B Or 3440 nuclear gauge is to be correlated. As Indicated In Part 3.5, Correlate Only In The Backscatter Position.

Test Number	Core Density lb./ft.^{3}	Core Density kg/m^3	Backscatter Density Average lb./ft.^{3}	Backscatter Density Average kg/m^3	Difference lb./ft.^{3}	Difference kg/m^3
1	144.6	2316	142.0	2275	2.6	42
2	145.0	2323	143.6	2300	1.4	22
3	141.9	2373	139.9	2241	2.0	32
4	142.7	2286	140.1	2244	2.6	42
5	144.6	2316	138.5	2219	6.1	98
6	144.0	2307	143.6	2300	0.4	6
7	142.2	2278	141.3	2263	0.9	14
8	143.3	2295	140.8	2255	2.5	40
					8/18.5	8/296
					= 2.31	= 37

Thus 36 kg/m^3 (2.3 lb./ft.^{3}) will be added to each wet density reading on this lift.

Note - The 97 kg/m^2 (6.1 lb./ft.^{3}) difference in test number 5 is NOT discarded since the technician had no reason to suspect a problem with the gauge reading or the core density.

IMPORTANT: The correlation factor should be less than 80 kg/m^3 (5 lb./ft.^{3}). When the correlation is greater than or equal to five PCF, the following should be checked:

4.2.1 Possible error in core or gauge procedure, especially gauge seating and standard count.

4.2.2 Possible defect in nuclear gauge - recheck standard count and statistical stability.

4.2.3 Possible error in equipment or procedure that was used for core density determination. Possible core damage.

4.2.4 Possible thin-lift effects. Refer to Materials Manual Procedure MT-212, item 9, on thin lift corrections. Thin lift adjustments must not be made on plant mix acceptance tests without first consulting the Materials Bureau.

Note - CORRECTIONS OF MORE THAN 80 kg/m^3 (5 lb./ft.^{3}) MUST BE APPROVED BY THE MATERIALS BUREAU.

METHODS OF SAMPLING AND TESTING
MT 314-04
METHOD OF TEST FOR BULK SPECIFIC GRAVITY OF COMPACTED BITUMINOUS MIXTURES
(MODIFIED AASHTO T 166)

1 Scope:

1.1 This method of test covers the determination of bulk specific gravity of specimens of compacted bituminous mixtures.

1.2 *Definition: Bulk Specific Gravity (of Solids) – The ratio of the weight in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the weight in air of equal density of an equal volume of gas free distilled water at a stated temperature. The form of the expression shall be:*

Bulk Specific Gravity x/y °C

where:

x = temperature of the material

y = temperature of the water.

1.3 This method should not be used with samples that contain open or interconnecting voids and/or absorb more than 2 percent of water by volume, as calculated in section 6.2 or 9.2.

1.4 The bulk specific gravity of the compacted bituminous mixtures may be used in calculating the unit weight of the mixture.

1.5 The values stated in SI units are to be regarded as the standard.

2 Referenced Documents:

2.1 ***AASHTO:***
M 231 Weighing Devices Used in the Testing of materials
T 166 Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
T 275 Bulk Specific Gravity of Compacted Asphalt Mixtures Using Paraffin-Coated Specimens

MT Manual:
MT-315 Bulk Specific Gravity of Compacted Asphalt Mixtures Using Paraffin-Coated Specimens

3 Test Specimens:

3.1 Test specimens may be either laboratory-molded asphalt mixtures or from HMA pavements. The mixtures may be surface or wearing course, binder or leveling course, or hot mix-base.

3.2 *Size of Specimens* – It is recommended that: (1) the diameter of cylindrically molded or cored specimens, or the length of the sides of sawed specimens, be at least equal to four times the maximum size of the aggregate; and (2) the thickness of specimens be at least one and one-half times the maximum size of the aggregate.

3.3 Specimens shall be taken from pavements with a core drill, diamond or carborundum saw, or by other suitable means.

3.4 Care shall be taken to avoid distortion, bending, or cracking of specimens during and after the removal from the pavement or mold. Specimens shall be stored in a safe, cool place.

3 Test Specimens: (continued)

3.5 Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

3.6 If desired, specimens may be separated from other pavement layers by sawing or other suitable means. Care should be exercised to ensure sawing does not damage the specimens.

METHOD A:

4 Apparatus:

4.1 *Weighing Device* – The weighing device shall have sufficient capacity, be readable to 0.01 percent of the sample mass, or better, and conform to the requirements of AASHTO M 231. The weighing device shall be equipped with suitable suspension apparatus and holder to permit weighing the specimen while suspended from center of scale pan of the weighing device.

4.2 *Suspension Apparatus* - The wire suspending the container shall be the smallest practical size to minimize any possible effects of a variable immersed length. The suspension apparatus shall be constructed to enable the container to be immersed to a depth sufficient to cover it and the test sample during weighing. Care should be exercised to ensure no trapped air bubbles exist under the specimen.

4.3 *Water Bath* - for immersing the specimen in water while suspended under the balance, equipped with an overflow outlet for maintaining a constant water level.

5 Procedure:

5.1 Dry the specimen to a constant mass. Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F), and record the dry mass as A. Immerse each specimen in water at 25 ± 1°C (77 ± 1.8°F) for 4 ± 1 minute and record the immersed mass as C. Remove the specimen from the water, damp-dry the specimen by blotting with a damp towel as quickly as possible, and determine the surface-dry mass as B. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen. Each specimen shall be immersed and weighed individually. (See Note 1, Note 2 & Note 3)

Note 1 - Constant mass is defined as the mass at which further drying at 52 ± 3°C (125 ± 5°F) does not alter the mass by more than 0.05 percent in a 2 hour drying interval. Recently molded laboratory samples, which have not been exposed to moisture, do not require drying. Core samples may be air dried in lieu of oven drying if results are proven not to differ from the oven drying method. The oven drying method is the standard and shall be used in case of dispute.

Note 2 - If desired, the sequence of testing operations may be changed to expedite the test results. For example, first the immersed mass C can be taken, then the surface-dry mass B, and finally the dry-mass A.

Note 3 - Terry cloth has been found to work well for the absorbent cloth. Damp is considered to be when no water can be wrung from the towel.

6 Calculation:

6.1 Calculate the bulk specific gravity of the specimen as follows (round and report the value to the nearest three decimal places):

$$\text{Bulk Specific Gravity} = \frac{A}{B - C}$$

6 Calculation: (continued)

where:

A = mass in grams of the specimen in air,

B = mass in grams of the surface-dry specimen in air,

C = mass in grams of the specimen in water.

6.2 Calculate the percent of water absorbed by the specimen (on a volume basis) as follows:

$$\text{Percent of Water Absorbed by Volume} = \frac{B-A}{B-C} x100$$

6.3 If the percent of water absorbed by the specimen as calculated in section 6.2 exceeds 2 percent, use MT- 315 to determine the bulk specific gravity.

METHOD B:

7 Apparatus:

7.1 *Weighing Device* – shall have sufficient capacity, readable to 0.1 percent of the sample mass or better, and conforming to the requirements of AASHTO M 231.

7.2 *Water Bath* - thermostatically controlled so as to maintain the bath at 25 ± 0.5°C (77 ± 0.9°F).

7.3 *Thermometer* - ASTM 17C (17F), having a range of 19 to 27°C (66 to 80°F), graduated in 0.1°C subdivisions.

7.4 *Volumeter,* calibrated to 1200 mL, or an appropriate capacity depending upon the size of the test sample. The volumeter shall have a tapered lid with a capillary bore.

8 Procedure:

8.1 Dry the specimen to a constant mass. Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F) and record the dry mass as A. Immerse the specimen in the water bath, and let it saturate for at least 10-minutes. At the 10-minute period, fill a calibrated volumeter with distilled water at 25 ± 1°C (77 ± 1.8°F). Remove the saturated specimen from the water bath, damp-dry the specimen by blotting with a damp towel as quickly as possible. Weigh the specimen and record the surface-dry mass as B. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen. (See Note 1, Note 2 & Note 3)

8.2 Place the specimen in the volumeter, and let it stand for at least 60 seconds. Bring the temperature of the water to 25 ± 1°C (77 ± 1.8°F), and cover the volumeter, making certain that some water escapes through the capillary bore of the tapered lid. Wipe the volumeter dry with a dry absorbent cloth, and weigh the volumeter and its contents (Note 4). Record this weight as *E*.

Note 4 – If desired the sequence of testing operations can be changed to expedite the test results. For example, first the mass of the saturated, damp-dry specimen B can be taken. Then the volumeter containing the saturated specimen and water E can be weighed. The dry mass of the specimen A can be determined last.

Note 5 – Method B is not acceptable for specimens that have more than 6 percent voids.

9 Calculations:

9.1 Calculate the bulk specific gravity of the specimen as follows (report the result to the nearest three decimal places).

$$\text{Bulk Specific Gravity} = \frac{A}{B+D-E}$$

where:

A = mass in grams of the dry specimen,

B = mass in grams of the surface-dry specimen,

`*D* = Mass in grams of the volumeter filled with water at 25 ± 1°C (77 ± 1.8°F), and

E = mass in grams of the volumeter filled with the specimen and water at 25 ± 1°C (77 ± 1.8°F).

9.2 Calculate the percent of water absorbed by the specimen (on a volume basis) as follows:

$$\text{Percent of Water Absorbed by Volume} = \frac{B-A}{B+D-E} x100$$

9.3 If the percent of water absorbed by the specimen as calculated in Section 8.2 exceeds 2 percent, use MT- 315 to determine the bulk specific gravity.

METHOD C (RAPID TEST):

10 Procedure:

10.1 This procedure can be used for testing specimens, which are not required to be saved and which contain a substantial amount of moisture. Specimens obtained by coring or sawing can be tested the same day by this method.

10.2 The testing procedure shall be the same as in Sections 5 and 8 except for the sequence of operations. The dry mass *A* of the specimen is determined last as follows:

10.3 Place the specimen in a large, flat-bottomed drying pan of known mass. Place the pan and specimen in a 110 ± 5°C (230 ± 9°F) oven. Leave the specimen in the oven until it can be easily separated to the point where the particles of the fine aggregate-asphalt portion are not larger than 6.4 mm (1/4 in.). Place the separated specimen in the 110 ± 5°C (230 ± 9°F) oven, and dry to a constant mass. Constant mass shall be defined as the weight at which further drying at 110 ± 5°C (230 ± 9°F) does not alter the mass by more than 0.05 percent when weighed at 2-hour intervals.

10.4 Cool the pan and specimen to room temperature at 25 ± 5°C (77 ± 9°F). Determine the mass of the pan and specimen, subtract the mass of the pan and record the dry mass *A*.

11 Calculations:

11.1 Calculate the bulk specific gravity in Sections 6.1 and 9.1.

12 Report:

12.1 The report shall include the following:

12.1.1 The method used (*A*,*B*, or *C*).

12.1.2 Bulk Specific Gravity reported to the nearest three decimal places.

12 Report: (continued)

12.1.3 Absorption reported to the nearest hundredth.

13 Precision:

13.1 Duplicate specific gravity results by the same operator should not be considered suspect unless they differ more than 0.02.

METHODS OF SAMPLING AND TESTING
MT 315-04
METHOD OF TEST FOR BULK SPECIFIC GRAVITY OF COMPACTED BITUMINOUS MIXTURES USING PARAFFIN-COATED SPECIMENS
(MODIFIED AASHTO T 275)

1 Scope:

1.1 This method of test covers the determination of bulk specific gravity of specimens of compacted bituminous mixtures.

1.2 *Definition: Bulk Specific Gravity (of Solids) – The ratio of the weight in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the weight in air of equal density of an equal volume of gas free distilled water at a stated temperature. The form of the expression shall be:*

Bulk Specific Gravity x/y °C

where:

x = temperature of the material

y = temperature of the water.

1.3 This method should be used with samples that contain open or interconnecting voids and/or absorb more than 2 percent of water by volume, as determined by MT-314.

1.4 The bulk specific gravity of the compacted bituminous mixtures may be used in calculating the unit weight of the mixture.

2 Referenced Documents:

2.1 ***AASHTO:***

M 231 Weighing Devices Used in the Testing of materials
T 166 Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens
T 275 Bulk Specific Gravity of Compacted Asphalt Mixtures Using Paraffin-Coated Specimens

MT Manual:

MT-314 Bulk Specific Gravity of Compacted Asphalt Mixtures Using Saturated Surface-Dry Specimens

3 Test Specimens:

3.1 Test specimens may be either laboratory-molded bituminous mixtures or from bituminous pavements. The mixtures may be surface or wearing course, binder or leveling course, or hot mix-base.

3.2 *Size of Specimens* – It is recommended that: (1) the diameter of cylindrically molded or cored specimens, or the length of the sides of sawed specimens, be at least equal to four times the maximum size of the aggregate; and (2) the thickness of specimens be at least one and one-half times the maximum size of the aggregate.

3.3 Pavement specimens shall be taken from pavements with a core drill, diamond or carborundum saw, or by other suitable means.

3.4 Care shall be taken to avoid distortion, bending, or cracking of specimens during and after the removal from the pavement or mold. Specimens shall be stored in a safe, cool place.

3 Test Specimens: (continued)

3.5 Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

3.6 If desired, specimens may be separated from other pavement layers by sawing or other suitable means. Care should be exercised to ensure sawing does not damage the specimens.

METHOD A:

4 Apparatus:

4.1 *Balance* – The balance shall have sufficient capacity, be readable to 0.01 percent of the sample mass, or better, and conform to the requirements of AASHTO M 231. The weighing device shall be equipped with suitable suspension apparatus and holder to permit weighing the specimen while suspended from center of scale pan of balance.

4.2 *Suspension Apparatus* - The wire suspending the container shall be of the smallest practical size to minimize any possible effects of a variable immersed length. The suspension apparatus shall be constructed to enable the container to be immersed to a depth sufficient to cover it and the test sample during weighing.

4.3 *Water Bath* - for immersing the specimen in water while suspended under the balance, equipped with an overflow outlet for maintaining a constant water level.

5 Procedure:

5.1 *Mass of Uncoated Specimens* - Weigh the specimen after it has been dried to a constant mass. Designate this mass as *A*.

Note 1 - Constant mass shall be defined as the mass at which further drying 52 ± 3ºC (125 ± 5ºF) at does not alter the mass by more than 0.05 percent. Samples shall initially be dried overnight at 52 ± 3ºC (125 ± 5ºF) and then weighed at two hour drying intervals.

5.2 *Mass of Coated Specimen in Air* – Coat the test specimen on all surfaces with melted paraffin sufficiently thick to seal all voids. Allow the coating to cool in air at room temperature at 25 ± 5ºC (77 ± 9ºF) for 30 minutes and then weigh the specimen. Designate this mass as *D*.

Note 2 - If it is desired to utilize the specimen for further tests that require the removal of the paraffin coating, the specimen may be dusted with powdered talc prior to coating.

Note 3 – Application of the paraffin may be accomplished by chilling the specimen in a refrigerating unit to a temperature of approximately 4.5ºC (40ºF) for 30 minutes and then dipping the specimen in warm paraffin (5.5ºC or 10ºF above melting point).

5.3 *Mass of Coated Specimen in Water* – Weigh the coated specimen in water bath at 25 ± 1ºC (77 ± 2ºF). Designate this mass as *E*.

5.4 *Specific Gravity of Paraffin* – Determine the specific gravity of the paraffin at 25 ± 1ºC (77 ± 2ºF), if known, and designate this as *F*.

6 Calculation:

6.1 Calculate the bulk specific gravity of the specimen as follows (round and report the value to the nearest three decimal places):

6 **Calculation:** (continued)

Bulk Specific Gravity = $\dfrac{A}{D - E - \left(\dfrac{D - A}{F}\right)}$

where:

A = mass in grams of the dry specimen in air

B = mass in grams of the dry specimen plus paraffin coating in air

E = mass in grams of the dry specimen plus paraffin in water.

F = specific gravity of the paraffin at 25 ± 1ºC (77 ± 2ºF).

METHOD B:

7 **Apparatus:**

7.1 *Balance* – shall have sufficient capacity, readable to 0.1 percent of the sample mass or better, and conforming to the requirements of AASHTO M 231.

7.2 *Water Bath* - thermostatically controlled so as to maintain the bath at 25 ± 0.5°C (77 ± 0.9°F).

7.3 *Thermometer* - ASTM 17ºC (17ºF), having a range of 19 to 27°C (66 to 80°F), graduated in 0.1°C subdivisions.

7.4 *Volumeter* - calibrated to 1200 mL, or an appropriate capacity depending upon the size of the test sample. The volumeter shall have a tapered lid with a capillary bore.

8 **Procedure:**

8.1 Dry the specimen to a constant mass (See Note 1). Cool the specimen to room temperature at 25 ± 5°C (77 ± 9°F) and record the dry mass.

8.2 Coat the specimen with melted paraffin until sufficiently thick to seal all surface voids. Allow the coating to cool in air at room temperature for 30 minutes and then weigh the specimen (Notes 2 & 3).

8.3 Fill a calibrated volumeter with distilled water at 25 ± 5°C (77 ± 9°F). Place the coated specimen into a volumeter and cover the volumeter, making certain that some water escapes through the capillary bore in the tapered lid. Wipe the volumeter dry with a dry absorbent cloth and weigh the volumeter and its contents.

8.4 Determine the specific gravity of the paraffin at 25 ± 5°C (77 ± 9°F), if unknown.

9 **Calculations:**

9.1 Calculate the bulk specific gravity of the specimen as follows (round and report the value to the nearest three decimal places.

Bulk Specific Gravity = $\dfrac{A}{D - \left[E - C + \left(\dfrac{C - A}{F}\right)\right]}$

where:

A = mass in grams of the dry specimen,

C = mass in grams of the paraffin-coated specimen,

9 Calculations: (continued)

D = Mass in grams of the volumeter filled with water at 25°C (77°F)

E = mass in grams of the volumeter filled with the paraffin-coated specimen and water at 25°C (77°F)

F = specific gravity of the paraffin at 25 ± 1°C (77 ± 2°F).

10 Precision:

10.1 Duplicate specific gravity results by the same operator should not be considered suspect unless they differ more than 0.02.

METHOD OF SAMPLING AND TESTING
MT 316-04
METHOD OF SAMPLING RECYCLED PAVEMENT AND FIELD CONTROL OF RECYCLE PAVING

1 General:

1.1 This method is divided into four sections which are as follows:

1.2 **Section A**: Sampling pavement for Cold Recycling

1.3 **Section B:** Field Control of Cold Recycle Paving

1.4 **Section C**: Sampling Pavement for Hot Recycling

1.5 **Section D**: Field Control of Hot Recycle Paving

Each section of this method is to be used specifically for its respective purpose related to recycle paving.

SECTION A:

2 Sampling Pavement for Cold Recycling

2.1 Scope:

2.2 This section describes the procedure for sampling roadways for cold mix recycling. The first portion describes sampling procedures for design information to determine if recycling is possible. The second portion describes sampling procedures for mix design purposes.

3 Procedure:

3.1 Preliminary Sampling for Proposed Recycled Pavement

3.1.1 The project should be divided into at least three areas from which milled or cored samples are obtained. A minimum of three representative sample locations should be visually selected in each area. Samples weighing approximately sixty pounds and representative of the lifts to be recycled should be obtained from each location. If maintenance patches or other intermittent treatments occur within the area, the locations that samples were taken should be recorded and the samples properly labeled. The proposed depth for recycling the pavement should be recorded.

3.1.2 Sampling a Cold Recycled Pavement for Mix Design: Milled Sampling

3.1.2.1 The project should be divided into at least three areas from which samples are obtained. A minimum of three locations should be used for each area of sampling. Submit approximately one hundred pounds of milled plant mix from each location. Three core samples should be taken to correspond with each milled area. The core samples should be placed into sealed containers at the job site so that in-place moisture contents may be determined.

3.1.3 Submitting Samples:

3.1.3.1 Samples from different locations are to be kept separate and submitted to the Materials Bureau for testing. Pertinent information such as locations at which samples were taken and depth to which milling was performed should be submitted with the samples.

SECTION B:

4 Field Control of Cold Recycle Paving:

4.1 Scope:

4.1.1 This section describes the procedure for field control of cold recycle paving. The test procedure utilizes standard 50 blow Marshall specimens. The Marshall specimens will be fabricated at the job site and then transported to the Materials bureau for compression testing.

4.1.2 Material should be secured from either the feed hopper of the laydown machine or the windrow, depending on the paving operation. Enough material (at least 25 lbs.) should be obtained for both the molding of briquettes and moisture determination.

5 Procedure:

5.1 Determination of Moisture Content:

5.1.1 For moisture determination, a representative sample of 2000 grams shall be weighed and placed in a 140°F oven.

5.1.2 The sample shall be weighed at intervals with weight losses recorded until a stabilized condition is achieved. A moisture loss of less than 1.0 gram in one hour should be considered a stabilized condition. Moisture content may be determined by:

$$MoistureContent(\%) = \frac{WT(Initial) - WT(final)(100\%)}{WT(final)}$$

5.2 Briquette Fabrication:

5.2.1 Apparatus:

5.2.1.1 *Scoops*

5.2.1.2 *Thermometer*, - 50° to 150°F

5.2.1.3 *Balance* - 2 kg. Capacity for weighing batch samples and briquettes

5.2.1.4 *Mixing spoons*

5.2.1.5 *Spatulas*

5.2.1.6 *Standard Marshall compaction pedestal* - with molds and compaction hammer

5.2.1.7 *Extrusion jack*

5.2.1.8 Gloves and marking crayons

5.2.1.9 Pans for holding and warming specimens

5.2.1.10 *Oven* - capable of maintaining 140°F ±5°F

6 Preparation of Test Specimens:

6.1 Prepare three specimens for each test.

6.2 Thoroughly clean molds and hammer face. Place paper disk in bottom of molds. Warm molds and hammer to remove chill.

6.3 Weigh out individual briquette samples. It is recommended that a trial briquette, approximately 1140 grams, be molded initially to determine height. Weight of material should then be adjusted to produce 2-1/2" ±0.05" specimens.

6 Preparation of Test Specimens:

6.4 Warm individual specimens in 140°F oven for two hours. Note: This process has been found to develop a density of mix equal to the roller compaction on the roadway.

6.5 Mold briquettes using standard Marshall procedures (i.e., 50 blows applied to each face).

6.6 Curing specimens in molds for up to 24 hours before extruding may be necessary if distortion occurs at an earlier extrusion time. Molds should be placed on their sides to permit equal ventilation of both ends (remove paper disks).

6.7 Carefully extrude specimens from molds.

6.8 If, when extruded, briquettes are sufficiently strong to enable handling, proceed to weigh in air, weigh in water and weigh saturated surface dry.

6.9 If, when extruded, briquettes are too tender to handle, curing will be required until they can be handled. The bulk specific gravities may then be determined.

Bulk specific gravity is calculated as follows:

$$BulkSpecificGravity(BSG) = \frac{WTinAir}{WT(SSD) - WTinWater}$$

6.9 Once bulk specific gravities have been determined, carefully transport the specimens to the Materials Lab for compression testing.

6.10 Report the specific gravities that were measured and the location represented by the samples. The samples must be protectively wrapped for shipping and they must be numbered sequentially to maintain control of their origin and history.

7 Utilization of Final Record Samples:

7.1 The final record pavement core samples taken in accordance with MT 602 are designated for research. As soon as possible, these should be sent to the Materials Bureau, accompanied by Form No. 31. The location and sample number are to be entered on the form and the wrapped cores are to be sequentially numbered.

SECTION C:

8 Sampling Pavement for Hot Mix recycling:

8.1 Scope:

8.1.2 This section describes the procedure for sampling roadways for hot mix recycling. The first portion describes sampling procedures for design information to determine if recycling is possible. The second portion describes sampling procedures for mix design purposes.

9 Procedure:

9.1 Preliminary Sampling for Proposed Recycled Pavement:

9.1.2 The project should be divided into at least three areas from which milled or cored samples are obtained. A minimum of three representative sample locations should be visually selected in each area. Samples weighing approximately sixty pounds and representative of the lifts to be recycled should be obtained from each location. If maintenance patches or other intermittent treatments occur within the area, the locations that samples were taken from should be recorded and the samples properly labeled. The proposed depth for recycling the pavement should be recorded.

9.1 Preliminary Sampling for Proposed Recycled Pavement: (continued)

To complete assessment of a potentially recyclable pavement, submit information about sources of aggregate used on the original project. In addition, send a minimum of 350 pounds of material to the Materials Bureau from a source which may be used as a virgin aggregate in the recycle mix.

10 Sampling a Hot Recycled Pavement for Mix Design:

10.1 Milled Sampling:

10.1.1 The project should be divided into at least three areas from which samples are obtained. A minimum of three locations should be used for each area of sampling. Submit approximately one hundred pounds of milled plant mix from each location. Three core samples should be taken to correspond with each milled area.

11 Stockpile Sampling:

11.1 Stockpiles of crushed reclaimed plant mix shall be sampled in accordance with MT 201, paragraph 10.

Note - Stockpile sampling requires particular care to avoid segregation. Samples should be taken from a near vertical face and should be secured by reducing the sample to 300-pounds by the quartering method or with a sample splitter. Due to the time required t extract and analyze the reclaimed plant mix, samples should be submitted as soon as one-third of the reclaimed mat stockpile has been produced.

11.2 To complete the mix design, 350 pounds of aggregate from the stockpiles of virgin aggregate, along with the appropriate forms, are required. The samples and documentation may be submitted when, in the judgment of the Project Manager, they are representative of the material to be incorporated into the recycled plant mix.

SECTION D:

12 Field Control of Hot Recycle Paving:

12.1 Scope:

12.1.2 This section describes the procedure for field control of hot recycle paving.

13 Procedure:

13.1 The crushed reclaimed mate shall be sampled in accordance with MT 201, paragraph 11: "Production sample shall be taken not less than every four hours. The sample shall be sieved and the percentage of oversize recorded. One sample of approximately 15 pounds shall be taken and submitted to the Materials Bureau every three days."

13.2 The aggregate incorporated into the mix shall be subject to all of the controls of a normal plant mix operation. The output of the plant will be subjected t field control Marshall testing with the same frequency as a conventional mix.

13.3 Monitors of established production of recycled plant mix shall be taken the first three days and the first day of every week thereafter or until otherwise informed by the Materials Bureau.

13.4 The samples shall be placed in a new double paper bag with completed form No 98 inserted between the sacks to keep it clean. The bag should be securely tied and marked as to sample number, stationing, lane and lift. This same information shall be placed on each Daily Plant Mix Report. Several of these paper bags can be packed into a sample sack for transmittal to the laboratory. Care should be taken to see that no movement is possible, or broken bags and mixed samples will result.

14 Utilization of Final Record Samples:

14.1 The final record pavement core samples taken in accordance with MT 602 are designated for research. As soon as possible, these should be sent to the Materials Bureau, accompanied by Form No. 31. The location and sample number are to be entered on the form and the wrapped cores are to be sequentially numbered.

METHOD OF SAMPLING AND TESTING
MT 317-04
PROCEDURE FOR MONITORING IN-PLACE BITUMINOUS PAVEMENT DENSITY AND AIR VOIDS

1 Scope:

1.1 This test method covers the procedure for establishing a density and air voids database utilizing final record cores and cores taken from designated projects meeting the criteria described in 2.2.

The purpose of this method is to determine how these projects are influenced by traffic compaction, climate and age.

2 Procedure:

2.1 Initial pavement density and air void data will be obtained from final record cores taken on those bituminous pavements, built using anti-rutting specifications. Reporting of pavement density and air void data will be done on the final record core report.

2.1.1 Obtain core bulk specific gravity by using Method B procedure outlined in MT-314.

2.1.2 Determine core maximum mixture specific gravity by running the Rice Method (MT-321) of Determining Maximum Specific Gravity of Bituminous Paving Mixtures.

2.1.3 Calculate core air void content using:

$$V_V = \frac{G_{CM} - G_{MB}}{G_{CM}} x100$$

where:

V_v = volume of air voids as percent of the bulk volume of specimen.

G_{cm} = maximum mixture specific gravity.

G_{mb} = measured bulk specific gravity of compacted mixture.

2.2 Monitoring of density and air voids will be accomplished by coring the designated pavements annually for five years. Usually, only three projects will be monitored, but additional ones may be added at the discretion of the District. The District shall select the three projects based upon the following criteria:

2.2.1 Projects constructed under the anti-rutting specification.

2.2.2 Average daily traffic at 2000 or greater.

2.2.3 25% heavy trucks or greater. (T »25).

2.2.4 Projects using different material characteristics, i.e., aggregates, asphalt grades, additives, etc.

METHOD OF SAMPLING AND TESTING
MT 318-04
PROCEDURE FOR USING DRY ICE TO OBTAIN CORES FROM HOT PLANT MIX SURFACING

1 Scope:

1.1 This procedure is for obtaining a core from the plant mix surfacing as soon as the finish roller has completed rolling while the plant mix is still hot. This is a procedure for obtaining a quick comparison of density with the nuclear device. This method is not as accurate a method as MT 313 and therefore, does not replace it.

2 Apparatus:

2.1 *Coring Machine* – a motor driver core machine that is capable of obtaining a 4-inch diameter core the full depth of the bituminous paving mixtures.

2.2 *Dry Ice Making Machine* – The machine must produce approximately a 16 oz. Block of dry ice. Dry ice may also be purchased from a commercial source.

2.3 *Insulated Ice Chest* – The ice chest should be large enough to carry a block of dry ice. Once should be able to remove the dry ice easily.

2.4 *Asbestos Gloves or Tongs for Handling Dry Ice* – warning: dry ice may cause severe burns if not handled properly.

2.5 *Nuclear Device* – The device must be capable of giving results in pounds per cubic foot.

2.6 *Balance and Water Container for Obtaining Specific Gravity of Core* – The sensitivity should be 0.5 g. or less.

2.7 *Miscellaneous Equipment* – Seating sand for Nuclear Device, broom for sweeping sand off plant mix, marking chalk and sampling sacks or heavy paper for covering dry ice.

3 Procedure:

3.1 Dry ice will be made the day before by using the dry ice machine and storing the ice in an insulated ice chest. (At least enough ice to make a volume of 10" x 10" x 2", is recommended.)

3.2 Two test sites will be selected for obtaining cores. As soon as finish rolling is completed, density tests on the plant mix surfacing will be taken with a nuclear device. The exact location where the nuclear test was taken will be outlined with marking chalk. Four tests at 90° intervals will be taken and the results averaged.

3.3 The seating sand will be removed and the dry ice will be placed on the outlined spot. The recommended time for cooling the plant mix surfacing is: 1"-2" thick, 20 minutes minimum; greater than 2" and up to 5" thick, 30 minutes minimum.

3.4 Coring will proceed as soon as the dry ice is removed from the plant mix surfacing. If the coring machine moves or shifts during coring operation, it is possible to break or distort the core, resulting in improper densities. Special care is needed for following the coring procedure so a good core is obtained. If the core is segregated or separated in any way, additional cores should be taken and more cooling time will be required.

3 **Procedure:** (continued)

3.5 Failure to keep constant downward pressure on the drill bit could distort the core and polish the diamond bit. This shortens the life of the core bit. If the core bit binds, the core is usually ruined for density testing and the bit could be burned, thus ruining the bit. Also, if the operator applies too much pressure to the coring bit, this could result in breaking the material, ruining the core for density testing.

3.6 After the complete core is obtained, the core will be thawed by being placed on the hot plant mix surfacing for about 20 minutes. (The core should be turned about every 4 or 5 minutes so all sides are the same temperature.)

3.7 After the core has been thawed and dry, the specific gravity of the core will be obtained according to MT-314, Method of Test for Bulk Specific Gravity of Compacted Bituminous Mixture.

METHODS OF SAMPLING AND TESTING
MT 319-04
METHOD OF TEST FOR DETERMINING THE ASPHALT BINDER CONTENT OF HOT-MIX ASPHALT (HMA) BY THE IGNITION METHOD

1 Scope:

1.1 This test method covers the determination of asphalt binder content of HMA mixtures by ignition at temperatures that reach the flashpoint of the binder in a furnace. The means of sample heating may be the convection method or the direct infrared (IR) irradiation method. The aggregate remaining after burning can be used for sieve analysis using MT-320.

1.2 The values in metric units are to be regarded as the standard.

1.3 This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2 Referenced Documents:

2.1 ***AASHTO:***
M 231 Weighing Devices Used in the Testing of Materials

MT Manual:
MT 202 Sieve Analysis for Fine and Coarse Aggregate
MT 303 Method of Sampling Bituminous Paving Mixtures
MT 312 Determining Moisture Content of Bituminous Mixtures
MT 320 Mechanical Analysis of Aggregate Recovered from Ignition Oven Burn
MT 325 Method of Determining Moisture Content of Bituminous Mixtures or Aggregate Using Microwave Ovens
Manufacturer's Operation Manual for equipment used

3 Summary of Test Method:

3.1 The asphalt binder in the paving mixture is ignited using the furnace equipment applicable to the particular method. The asphalt binder content is calculated as the difference between the initial mass of the hot-mix asphalt and the mass of the residual aggregate. The asphalt content is expressed as mass percent of moisture-free mixture.

4 Significance and Use:

4.1 This method can be used for quantitative determinations of asphalt binder content and gradation in HMA mixtures and pavement samples for quality control, specification acceptance, and mixture evaluation studies. This method does not require the use of solvents. Aggregate obtained by this test method may be used for gradation analysis according to MT-320.

5 Sampling:

5.1 Obtain samples of freshly produced hot-mix asphalt (HMA) in accordance with MT-303.

5.2 The test specimen shall be the end result of quartering a larger sample taken in accordance with MT-309.

5.3 If the HMA is not sufficiently soft to separate with a spatula or trowel, place it in a large flat pan or glass dish in an oven (conventional or microwave). Heat sample to separate. Excessive heat may cause asphalt drain down.

5 Sampling: (continued)

5.4 The size of the test sample shall be governed by the nominal maximum aggregate size of the HMA and shall conform to the mass requirement shown in Table 1. Specimen sizes shall not be more than 400 grams greater than the minimum recommended specimen mass.

Note 1—Large samples of fine mixes tend to result in incomplete ignition of asphalt.

Table 1—Mass Requirements

Nominal Max Agg Size, mm	Sieve Size	Min Mass of Specimen, g
4.75	No. 4	1200
9.5	⅜ in.	1200
12.5	½ in.	2000
19.0	¾ in.	2000
25.0	1 in.	3000
37.5	1½ in.	4000

6 Correction Factor:

6.1 This method may be affected by the type of aggregate in the mixture. Accordingly, to optimize accuracy, a correction factor will be established with the testing of a set of correction factor samples for each type of HMA. This procedure must be performed before any acceptance testing is completed. Certain aggregate types may result in an unusually high correction factor (>0.5 percent) and erroneous gradation results due to aggregate breakdown. Such mixes should be corrected and tested as described in Section 6.8.

6.2 The process for determining a correction factor should be repeated each time there is a new HMA design. Each ignition furnace shall have it's own, unique correction factor determined in the location where testing will be performed.

6.3 According to the requirements of Section 5, prepare two correction samples at the design asphalt content using a buttered bowl. Aggregate used for the correction factor specimens shall be sampled from stockpiled material produced and designated to be used on the candidate project. Any method may be used to combine the aggregates. If aggregate bin proportions are used, an additional "blank" specimen shall be batched and tested for aggregate gradation according to MT- 202. The washed gradation shall fall within the mix design tolerances.

Note 2—This is performed in the Helena Mix Design Laboratory for MDT testing.

6.4 The freshly mixed specimens may be placed directly in the sample baskets. If allowed to cool, the samples must be preheated in a conventional oven to compaction temperature. Do not preheat the sample baskets.

6.5 Test specimens in accordance with Sections 8 and 9.

6.6 Once all of the correction factor specimens have been burned, determine the measured asphalt binder contents for each sample by calculation or from the printed tickets.

6.7 If the difference between the measured asphalt binder contents of the two samples exceeds 0.15 percent, repeat the two tests and, from the four tests, discard the high and low results. Determine the correction factor from the two remaining results. Calculate the difference between the actual and measured asphalt binder contents for each sample. The correction factor is the average of the differences expressed in percent by weight of the asphalt mixture.

6.8 Correction Factor Temperature Adjustment:

6 Correction Factor: (continued)

6.8.1 For the convection-type furnace, if the correction factor exceeds 1.0 percent, lower the test temperature to 482 ± 5°C (900 ± 8°F) and repeat test. Use the correction factor obtained at 482°C even if it exceeds 1.0 percent.

6.8.2 For the direct irradiation-type furnace, the Option 2 burn profile should be used for most materials. Option 1 is designed for very soft aggregate (such as dolomites) that typically require a large aggregate correction factor (greater than 1%). Option 2 is designed for samples that may not burn completely using the DEFAULT burn profile and is appropriate for most of Montana aggregates.

6.9 Test Temperature:

6.9.1 For the convection-type furnace, the temperature for testing HMA samples in Section 8.1.1 shall be the same temperature selected for testing mixture correction samples.

6.9.2 For the direct IR irradiation-type furnace, the burn profile for testing HMA samples in Sections 8.1.2 shall be the same burn profile selected for testing mixture correction samples.

7 Apparatus:

7.1 *Ignition furnace* - A forced air ignition furnace that heats the samples by either convection method or direct IR irradiation method. The convection-type furnace must be capable of maintaining the temperature at 578°C (1072°F). The furnace shall have an internal balance thermally isolated from the furnace chamber and accurate to 0.1 g. The balance shall be capable of weighing a 3500 gram sample in addition to the sample baskets. A data collection system will be included so that the weight can be automatically determined and displayed during the test. The furnace shall have a built in computer program to calculate change in mass of the sample baskets and provide for the input of a correction factor. The furnace shall provide a printed ticket with the initial specimen mass, specimen mass loss and test time. The printed ticket may also include the correction factor and corrected asphalt content (percent) if not calculated by hand. The furnace chamber dimensions shall be adequate to accommodate a sample size of 3500 grams. The furnace shall provide an audible alarm and indicator light when the sample mass loss does not exceed 0.01 percent of the total sample mass for three consecutive minutes. The furnace door shall be equipped so that the door cannot be opened during the ignition test. The furnace shall be vented into a hood or to the outside. The furnace shall have a fan with capability to pull air through the furnace to expedite the test and to reduce the escape of smoke into the laboratory.

7.2 *Sample basket(s)* - of appropriate size that allows the samples to be thinly spread and allows air to flow through and around the sample particles. Sets with two or more baskets shall be nested. The sample shall be completely enclosed with screen mesh, perforated stainless steel plate, or other suitable material.

Note 3 - Screen mesh or other suitable material with maximum and minimum opening of 2.36 mm (No. 8) and 600 microns (No. 30), respectively, has been found to perform well.

7.3 *Catch Pan* - of sufficient size to hold the sample basket(s) so that aggregate particles and melting asphalt binder falling through the screen mesh are caught.

7.4 *Oven* - capable of maintaining 125 ± 5°C (257 ± 9°F).

7.5 *Balance* - of sufficient capacity and conforming to the requirements of M 231, Class G 2, for weighing specimen in basket(s).

7.6 *Safety Equipment* - face shield, high temperature gloves, a heat resistant surface capable of withstanding 650°C (1202°F) and a protective cage capable of surrounding the sample baskets during the cooling period.

7.7 *Miscellaneous Equipment* - a pan larger than the sample basket(s) for transferring sample after ignition, spatulas, bowls, wire brushes, and other manufacturer's equipment.

8 Test Procedures:

8.1 Test Initiation:

8.1.1 For the convection-type furnace, preheat the ignition furnace to 538°C (1000°F) or as determined in Section 6.9.1. Manually record the furnace temperature (set point) prior to the initiation of the test if the furnace does not record automatically.

8.1.2 For the direct IR irradiation-type furnace, preheat furnace to 420°C (788°F) or manufacturers recommendation.

8.2 Determine the moisture content of the sample according to MT-312 or MT-325 at the beginning and middle of each production day and as needed.

8.3 Apply the correction factor for the specific mix to be tested as determined in Section 6 in the ignition furnace.

8.4 Weigh and record the mass of the sample basket(s) and catch pan (with guards in place).

8.5 Prepare the sample as described in Section 5. Evenly distribute this sample in the sample basket(s) that have been placed in the catch pan, taking care to keep the material away from the edges of the basket. Use a spatula or trowel to level the specimen.

8.6 Weigh and record the total mass of the sample, basket(s), catch pan, and basket guards. Calculate and record the initial mass of the specimen (total mass minus the mass of the specimen basket assembly).

8.7 Input the initial mass of the specimen to 0.1 of a gram for direct IR irradiation-type furnace or 1 gram for convection-type furnace into the ignition furnace controller. Verify that the correct mass has been entered.

8.8 Open the chamber door, and place the sample baskets in the furnace. Close the chamber door, and verify that the sample mass (including the basket(s)) displayed on the furnace scale equals the total mass recorded in Section 8.6 within ± 5 g. Differences greater than 5 g or failure of the furnace scale to stabilize may indicate that the sample basket(s) are contacting the furnace wall. Initiate the test by pressing the start/stop button. This will lock the sample chamber and start the combustion blower.

Note 4- -The furnace temperature will drop below the set point when the door is opened, but will recover with the door closed and when ignition occurs. Sample ignition typically increases the temperature well above the set point, depending on sample size and asphalt content.

8.9 Allow the test to continue until the stable light and audible stable indicator indicate the test is complete (the change in mass does not exceed 0.01 percent for three consecutive minutes). Press the start/stop button. This will unlock the sample chamber and cause the printer to print out the test results.

8.10 Use the corrected asphalt binder content (percent) from the printed ticket. If a moisture content has been determined, subtract the moisture content from the printed ticket corrected asphalt content, and report the difference as the corrected asphalt binder content.

8.11 Open the chamber door, remove the sample basket(s), and allow them to cool to room temperature (approximately 30 minutes). During cooling, make sure sample basket(s) are protected from contaminates.

9 Gradation:

9.1 Allow the specimen to cool to room temperature in the sample baskets.

9.2 Empty the contents of the baskets and the catch pan into a flat pan. Use a small wire sieve brush to ensure that any residual fines are removed from the baskets.

9.3 Perform the gradation analysis according to MT-320.

10 Report:

10.1 Report the corrected asphalt binder content to the nearest 0.01%, correction factor, temperature compensation factor (if applicable), total percent loss, sample mass and moisture content (if determined). Attach the original printed ticket to the report for units with internal balances.

Q:\MT-STD\F68.BurnOven.doc
MBA Form No. 68 (Rev. 02-09-04,AC)

MONTANA DEPARTMENT OF TRANSPORTATION
WORK SHEET FOR BURN OVEN TESTING

_ Metric/_English

Lab No._____ Project No._____ Name_____ Date_____

Asphalt Grade_____ Refinery _____ Mix Type_____

S.G. Asph._____ S.G. Agg.(Blend)___ Oven Correction Factor _____

Tested by_____

TEST / BRICK NO.											Day's Averages	Running Averages
Time Taken												
Basket Wt.												
Initial Sample + Basket Wt.												
Initial Sample Wt.												
After Burn Sample + Basket Wt.												
After Burn Sample Wt.												
Burn Oven % AC												
Correction Factor												
% Moisture												
_____ **ACTUAL % AC**												

METHOD OF SAMPLING AND TESTING
MT 320-04
MECHANICAL ANALYSIS OF AGGREGATE RECOVERED FROM IGNITION OVEN BURN (MT 319)

1 Scope:

1 This method of test covers a procedure for the determination of the particle size distribution of fine and coarse aggregates recovered from bituminous mixtures, using sieves with square openings.

2 Referenced Documents:

2.1 *AASHTO Standards:*
M 231 Weighing Devices Used in the Testing of Materials

MT Manual:
MT-405 Sieves for Testing Purposes
MT-417 Reducing Filed Samples to Testing Size

3 Apparatus:

3.1 *Balance* - The balance or scale shall have a capacity larger than the size of the sample being tested. The balance or scale used for weighing shall have a sensitivity of (0.1 grams) and conforming to the requirements of M 231.

3.2 *Sieves* - The sieves with square openings shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. Suitable sieve sizes shall be selected to furnish the information required by the specifications covering the material to be tested. The sieves shall conform to the requirements of MT-405, Wire Cloth Sieves for Testing Purposes.

3.3 *Container* - A container sufficient to contain the sample covered with water and to permit vigorous agitation without inadvertent loss of any part of the sample or water. The container used shall be approved by the District or Area Materials Supervisor prior to use.

3.4 Oven, Hot Plate or alternate heating source.

4 Sample:

4.1 The sample shall consist of the aggregate obtained from Bituminous Paving Mixtures from which the bituminous material has been ignited.

Note 1- A sample that is overloading screens will have to be split or quartered in accordance with MT-417, Reducing Field Samples to Testing Size, and graded separately and the weights combined to obtain a representative gradation. It requires amounts in excess of the following table to overload a screen.

4 **Sample:** (continued)

Screen Size	MAXIMUM WEIGHT RETAINED 203 mm Diameter (8" Diameter) Screen Maximum Grams	Maximum Pounds	304.8 mm Diameter (12" Diameter) Screen Maximum Grams	Maximum Pounds	14 3/4" X 22 3/4" Tray Gilson Screen Maximum Grams	Maximum Pounds
31.75 mm (1 1/4")			3821.9	8.4	11339.8	25
25.0 mm (1")			3057.5	6.7	9071.8	20
19.0 mm (3/4")			2598.9	5.7	7711.0	17
16.0 mm (5/8")			2293.2	5.1	6803.9	15
12.5 mm (2")			1987.4	4.4	5896.7	13
9.5 mm (3/8")			1223.0	2.7	3628.7	8
4.75 mm (4 M)	318	0.7	917.3	2.0	2721.5	6
2.36 mm (8 M)	194	0.4	436.5	0.9	1814.1	4
2.00 mm (10 M)	194	0.4	436.5	0.9	1814.1	4
425 µm (40 M)	194	0.4	436.5	0.9		
180 µm (80 M)	194	0.4	436.5	0.9		
75 µm (200 M)	194	0.4	436.5	0.9		

5 **Procedure:**

5.1 The sample shall be dried until further drying does not alter the weight 0.1 percent, constant mass. The total weight of aggregate in the bituminous mixture being tested is the sum of the weights of the dried aggregates and the mineral matter.

5.2 The test sample after being dried and weighed shall be placed in a container and covered with water. Add a sufficient amount of wetting agent (Note 2) to assure a thorough separation of the material finer than the 200 mesh from the coarser particles. The contents of the container shall be agitated vigorously and the wash water immediately poured over a nest of two sieves consisting of a 10 or 16 mesh sieve superimposed on a 200 mesh sieve. The use of a large metal spoon to stir and agitate the aggregate in the wash water has been found satisfactory.

Note 2 - Wetting agents may include any dispersing agent such as Calgon, Joy or other detergent, or a soap, which will promote the separation of fine material.

5.3 The agitation shall be sufficiently vigorous to result in the complete separation from the coarse particles of all particles finer than the 200 mesh sieve and bring them into suspension in order that they may be removed by decantation of the wash water. Care shall be taken to avoid, as much as possible, the decantation of the coarse particles of the sample. The operation shall be repeated until the wash water is clear.

5.4 The washed aggregate shall be dried to constant mass in an oven or alternate heating source and weighed to the nearest 0.1 grams.

5.5 The aggregate shall then be sieved over sieves of the various sizes required by the specification. The weight of material passing each sieve and the amount passing the 200 mesh sieve shall be recorded. The summation of these various weights must check the dried weight after washing within 0.3 percent of the total weight. The weights of fractions retained on the various sieves and the total passing the 200 mesh sieve shall be converted to percentages by dividing each by the total weight of aggregate in the bituminous mixture.

6 **Calculations:**

6.1 The individual weights retained must be converted to total weight passing each of the various sieves. The total weight passing is then divided by the total weight of the sample, multiplied by 100, which will result in the percent passing.

7 Report:

7.1 The results of the sieve analysis shall be reported as the total percentages passing each sieve size and reported to the nearest whole number for all material coarser than the 200 mesh. The 200 mesh material shall be reported to one tenth of one percent. Percentages shall be calculated on the basis of the total weight of the sample, including any material finer than the 200 mesh sieve.

GRADATION WORKSHEET EXAMPLE

Date:_____ Project_____

Termini_____ Sample Number_____

Before Wash 2405 After Wash 2352.2 LBW. 52.8

Wt. Retained	Wt. Pass.	Percent Passing
0.0	25M 2405	100
144.0	19M 2261	94
312.0	12.5M 2093	87
673.0	9.5M 1732	72
1322.0	4.75M 1083	45
1538.0	2.36M 867	36
1827.1	1.18M 577.9	24
2019.1	0.60M 385.9	16
2115.1	0.30M 289.9	12
2163.1	0.15M 241.9	10
2259.1	0.075M 145.9	6.1
2352.0	Dry Pan 53.0	

Remarks:

All weights are recorded to 0.1 of a gram.

GRADATION WORKSHEET

Date:_____ Project_____

Termini_____Sample Number_____

Before Wash _____ After Wash _____ LBW. _____

Wt. Retained	Wt. Pass.	Percent Passing
_____	25M _____	_____
_____	19M _____	_____
_____	12.5M _____	_____
_____	9.5M _____	_____
_____	4.75M _____	_____
_____	2.36M _____	_____
_____	1.18M _____	_____
_____	0.60M _____	_____
_____	0.30M _____	_____
_____	0.15M _____	_____
_____	0.075M _____	_____
_____	Dry Pan _____	

Remarks:

All weights are recorded to 0.1 of a gram.

METHODS OF SAMPLING AND TESTING
MT 321-04
PROCEDURE FOR DETERMINING MAXIMUM SPECIFIC GRAVITY OF BITUMINOUS PAVING MIXTURES - "RICE'S METHOD"
(Modified AASHTO T 209)

1 Scope:

1.1 This method covers the determination of maximum specific gravity of un-compacted bituminous paving mixtures commonly referred to as Rice Gravity.

2 Referenced Documents:

MT Materials Manual:
MT-303 Method of Sampling Bituminous Mixtures
MT-325 Method of Determining Moisture Content of Bituminous Mixtures Using Microwave Ovens

3 Apparatus:

3.1 *Balance* – with a capacity of 16,000 g sensitive to 0.1 g, to enable the maximum specific gravity of the un-compacted mix to be calculated to four significant figures (3 decimal places).

3.2 *Container* - Use a volumetric flask of 4000 ml as provided. The flask with a proper cover must be sufficiently strong to withstand a partial vacuum. The flask is provided with a rubber stopper and a hose connection. A small piece of fine wire mesh covering the hose opening will minimize loss of fines. The top surfaces of all containers shall be smooth and substantially plane.

3.3 *Vacuum Pump* - a motor driven vacuum pump, capable of maintaining at least 30 mm of Hg of vacuum, is used for removing air from the flask through the vacuum line (¼" dia. tubing).

3.4 *Water Bath* - Use the water bath (as provided) capable of maintaining a constant temperature of 25 ± 0.6°C (77 ± 1°F), to fill the 4000 ml flask.

3.5 *Calibration of Flask* - Calibrate the volumetric flask by determining the weight of the water required to fill it at 25 ± 0.6°C (77 ± 1°F). Accurate filling of the flask may be insured by using a glass capillary stopper which is inserted in the flask until water ceases to flow out of the top.

3.6 Te*st Samples* - The samples shall be obtained in accordance with MT-303.

4 Sample Size - Listed below:

Nominal Max. Size of Aggregate	Wt. of Sample
1"	2.5 Kg (5.50 lb.)
3/4"	2 Kg (4.40 lb.)
1/2"	1.5 Kg (3.30 lb.)
3/8"	1.0 Kg (2.20 lb.)
No. 4	0.5 Kg (1.10 lb.)

5 Procedure:

5.1 Separate the particles of the sample, taking care not to fracture the mineral particles, so that the fine aggregate portion is less than ¼ inch.

5 Procedure: (continued)

5.2 The sample may be heated if necessary to facilitate the break up of the sample.

NOTE 1 - If the sample is to be heated, it should be heated no more than 10 minutes at 149°C (300°F) or 5 minutes in the microwave oven. See microwave precautions on page 2 of 3 in MT-325.

5.3 Cool the sample to room temperature. Add sufficient water to flask (about 2000 ml) at 25 ± 0.6°C (77 ± 1°F). Weigh flask and water and designate weight as "D." (See Note 2). Record the weights on the worksheet. Add test sample and weigh. Designate the net weight of the sample as "A." (See Note 2).

NOTE 2 - "A" (net wt. dry sample) = *Weight of flask and water and sample - weight of flask and water*

"D" = *Weight of flask (calibrated) and water*

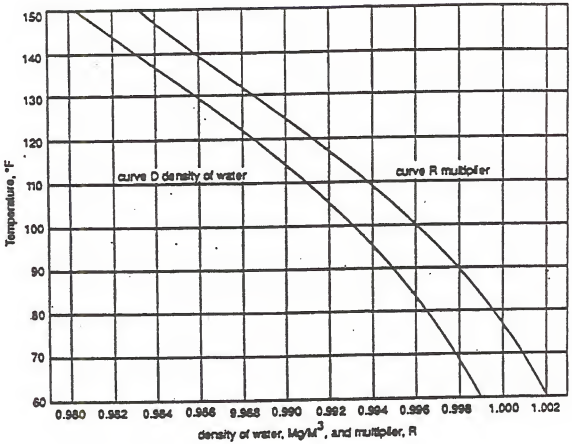
5.4 Remove entrapped air by subjecting the contents to a partial vacuum of 30 Hg mm or less gauge pressure for 15 ± 2 minutes. Agitate the container and contents either continuously by mechanical device or manually by vigorous shaking at intervals of about 2 minutes. (See note 3.)

NOTE 3 - If a wetting agent is desired, Aerosol OT in concentration of 0.01% or 1 ml of 10% solution in 1000 ml of water is recommended.

5.5 Flask Determination - Fill the flask with water (77 ± 1°F) and bring contents to a temperature of 77 ± 1°F in the constant temperature bath. Determine the weight of the flask filled with contents at 10 ± 1 min after completing the vacuum procedure 5.4. Designate the weight of flask with water and sample as E.

TEMPERATURE vs. WATER DENSITY CURVE

5.6 In lieu of using constant temperature water bath because of mechanical failure, a temperature vs. water density curve correction may be used. Determine the temperature of the water within flask and use the curve multiplier shown below, i.e., to correct the wt. of water at temperatures greater than or less than 77°F.


150
140
130
120
110
100
90
80
70
60
Temperature, °F
curve D density of water
curve R multiplier
0.980 0.982 0.984 0.986 0.988 0.990 0.992 0.994 0.996 0.998 1.000 1.002
density of water, Mg/M3, and multiplier, R

METHOD OF SAMPLING AND TESTING
MT 323-04
METHOD OF TEST FOR FABRICATING SPECIMENS FOR COMPRESSIVE STRENGTH OF BITUMINOUS MIXTURES
(Modified AASHTO T 167)

1 Scope:

1.1 This method of fabrication for compacted bituminous mixtures of the hot mixes, holt-laid type, for use in pavement surfaces and base courses, is intended to provide test specimens for measuring the loss of cohesion resulting from the action of water (MT-324) and the compressive strength of these paving mixtures.

2 Referenced Documents:

2.1 ***AASHTO:***
T 167 Standard Test Method for Compressive Strength of Bituminous Mixtures

MT Manual:
MT-308 Temperature/Viscosity Charts
MT-311 Marshall Method for Field Control of Hot Mix Asphalt Paving
MT-324 Effect of Water on Cohesion of Compacted Bituminous Mixtures

3 Apparatus:

3.1 *Mold* – The molds used for specimen fabrication consist of three principal parts: a heavy steel walled molding cylinder, a steel top plunger and a bottom plunger. The molding cylinder is machined and hardened with an inside diameter of 4 inches (100 mm) with a tolerance of +.005 inch (+.125/-.000mm) and approximately 7 inches (175 mm) in length. The top and bottom molding plungers will fit inside the molding cylinders tightly enough to uniformly compress the asphalt mixture. The plungers are designed not to jam within the molding cylinder. Vertical alignment is maintained by steel webbing connecting the top and bottom of each plunger. The top plunger is approximately 6.5 inches (162 mm) in length with a diameter of 3.996 inches and a tolerance of +.000/-.005 inches, and the bottom plunger will be approximately 2.0 inches (50 mm) in length with a diameter of 3.996 inches with a tolerance of +.000/-.005 inches.

Note 1- The lengths of the molding cylinder and plungers are not critical. When the molding cylinder is over the lower plunger and is resting on the temporary supports, the molding chamber created must be at least 6 inches (150 mm) in depth to accommodate an un-compacted sample and have room to start the top piston. The cylinder must not be more than two inches longer than the combined length of the upper and lower plunger to ensure unrestricted compression of the asphalt specimen.

3.2 *Supports* – Temporary supports will be provided to raise the molding cylinder enough to initiate double plunger action.

Note 2 -The mold, plungers and supports are used as accessories to a compressive press with a minimum capacity of 38,000 lbs.

3.3 *Oven* – The convection oven for the preparation of hot mixtures shall be capable of being set to maintain any desired temperature from room temperature to 325 °F (163 °C).

3.4 *Heating Device* - A small hot plate with a continuously variable heating rate, a sand bath, an infrared lamp or an oven shall be provided for supplying sufficient heat under the mixing bowl to maintain the aggregate and bituminous material at the desired temperature during mixing.

3.5 *Air Bath* – The air bath shall be capable of either manual or automatic control for storing the specimens at 77 ± 1 °F (25 ± 0.5 °C) immediately prior to making the compression test.

3 Apparatus: (continued)

3.6 *Mixing Machine* – The mixture should preferably be prepared in a mechanical mixer. Any type of mixer may be used provided it can be maintained at the required mixing temperature and will produce a well-coated, homogeneous mixture of the required size in 2 min. or less, and further provided that it is of such design that fouling of the blades will be minimized and each individual batch can be retrieved in essentially its entirety including asphalt and fines. Hand mixing may be used, if necessary, but for hot mixtures the time required to obtain satisfactory coating is often excessive and generally the test results are less uniform than when machine mixing is employed.

3.7 *Spatulas* - Limber for scraping the mixing bowl, and stiff, for spading the specimen in the mold, shall be provided.

3.8 *Balance* – A balance having a capacity of 5 kilograms or more and be sensitive to 0.1 gram or less.

4 Preparation of Test Mixtures:

4.1 The size of the individual batches shall be limited to the amount required for one test specimen. The percentage of asphalt cement can also be the optimum asphalt content as determined by Marshall Method for Field Control of Hot Mix Asphalt Paving (MT-311).

4.2 An initial batch shall be mixed for the purpose of "buttering" the mixture bowl and stirrers. This batch shall be emptied after mixing and the sides of the bowl and stirrers shall be cleaned of mixture residue by scraping with a small limber spatula but shall not be wiped with cloth or washed clean with solvent, except when a change is to be made in the binder or at the end of a run.

4.3 In preparing aggregates for making mixtures, a sieve analysis shall be made on each aggregate involved. All coarse and fine aggregates shall be separated individually and recombined in the necessary quantities to meet the formula under study. The weighed aggregate fractions for each batch shall be thoroughly mixed dry and then heated to the planned mix temperature in a convection oven before the bituminous material is added. A sufficient quantity of bituminous material for each batch shall be heated in a convection oven to the same temperature as the dry aggregates. Any residual bituminous material that is left over at the end of the day must be discarded.

4.4 When the bituminous material and dry aggregates have been brought to the mix temperature, the mixing bowl, which shall have been preheated to approximately the temperature of the aggregate, shall be charged with the preheated and dry mixed aggregate, the preheated bituminous material shall be weighed into the aggregate, and wet mixing shall be started and continued for not less than 90 s nor more than 120 s. Excessive loss of heat during mixing may be offset by the use of a small hot plate, sand bath, or infrared lamp under the mixing bowl, or a heating mantle may be used. The mixing bowl shall not be in direct contact with a hot plate, if used.

5 Molding and Curling Test Specimens:

5.1 Generally, the test specimens shall be cylinders with the same diameter tolerance as the molding cylinder and 4.0 ± 0.1 inches (100 mm = 2.5 mm) in height. It is recognized that the size of the test specimens has an influence on the results of the compressive strength tests.

5.2 Laboratory prepared mixtures shall be fabricated as quickly as possible after mixing as follows:

5.3 Mixtures from a field project shall be brought to molding temperature by careful, uniform heating immediately prior to molding. The approximate mixing temperature for a particular asphalt will produce a viscosity of 170±20 C_{st} obtained by using the temperature-viscosity charts in MT 308. The approximate compaction temperature for a particular asphalt will produce a viscosity of 280±30 C_{st} obtained by using the temperature-viscosity charts in MT 308.

5 Molding and Curling Test Specimens: (continued)

5.4 Mix the measured weights of asphalt cement and dry aggregate (90-120S) at the determined mix temperature.

5.5 While mixing is taking place, take the preheated mold and plungers (heated to the same temperature as the dry aggregate) and wipe them lightly with an oiled cloth to prevent sticking. Place the bottom plunger on the table of the press. Position the temporary supports on each side of the plunger and place the mold cylinder on them.

5.6 Pour the bituminous mixture from the mixing bowl into a large scoop. Scrape the mixing bowl with a spatula, do not clean with solvent.

5.7 Pour one half of the mixture from the scoop into the molding cylinder, using a spatula to obtain an even discharge. Spade vigorously twenty-five (25) times with a heated spatula. Fifteen of the blows will be delivered around the inside of the mold, to reduce honeycombing, and the remaining ten at random over the mixture. The remaining half of the mixture shall then be quickly transferred to the molding cylinder and a similar spading action repeated. The spatula should penetrate the mixture as deeply as possible. A spatula having a slightly curved cross-section has been used to advantage by some laboratories.

5.8 Round or cone-shape the top of the mixture to aid in firm seating of the upper plunger. Then place the upper plunger on the spaded mixture and slide the whole assembly under the press plates.

5.9 The mixture, with the temporary supports in place, shall be compressed between the top and bottom plungers to an initial load of about 150 psi to set the mixture against the sides of the mold. The load shall then be released and the support bars removed to permit full double-plunger action.

5.10 Smoothly and rapidly apply a load of approximately 3000 psi, maintain for 120S and release.

5.11 The specimen shall then be removed from the mold with an ejection device that provides a smooth, uniform rate of travel.

5.12 After removal from the mold, specimens shall be oven cured 15-24 hours at 140 ± 1°F (60 ± 0.5 °C). In case specimens are to be stored dry for more than 24 h from completion of oven curing to compression testing, they shall be protected from exposure to the air by sealing them in closely fitting, airtight containers.

METHOD OF SAMPLING AND TESTING
MT-324-04
METHOD OF TEST FOR
EFFECT OF WATER ON COHESION OF COMPACTED BITUMINOUS MIXTURES
(Modified AASHTO T 165)

1 Scope:

1.1 This method covers measurement of the loss of cohesion resulting from the action of water on compacted bituminous mixtures containing penetration grade asphalts. A numerical indeed of reduced cohesion is obtained by comparing the compressive strength of freshly molded and cured specimens with the compressive strength of duplicate specimens that have been immersed in water under prescribed conditions.

2 Referenced Documents:

2.1 ***AASHTO:***
T 67 Force Verification of Testing Machines
T 165 Effect of Water on Compressive Strength of Compacted Bituminous Mixtures

MT Manual:
MT-314 Method of Test for Bulk Specific Gravity of Compacted Bituminous Mixtures
MT-323 Fabricating Specimens for Compressive Strength of Bituminous Mixtures

3 Apparatus:

3.1 *High Temperature Water Bath* – One or more automatically controlled water baths shall be provided for immersing the specimens. The baths shall be of sufficient size to permit total immersion of the test specimens. They shall be so designed and equipped as to permit accurate and uniform control of the immersion temperature of 140 ± 2 °F (60 ± 1°C). They shall be constructed of or lined with copper, stainless steel, or other nonreactive material. The water used for the wet storage of the specimens shall be either distilled or otherwise treated to eliminate electrolytes and the bath shall be emptied, cleaned, and refilled with fresh water for each series of tests. Tap water can be used for wet storage if it can be shown that it does not affect the test results of the immersed specimens.

3.2 *Low temperature Water Bath* – A manually or automatically controlled water bath also shall be provided for bringing the immersed specimens to the temperature of 77±2 °F (25±1 °C) for the compression test. Any convenient pan or tank may be used provided it is of sufficient size to permit total immersion of the specimens.

3.3 *Balance* – A balance and a water bath with suitable accessory equipment will be required for weighing the test specimens in air and in water in order to determine their densities, the amount of absorption, and any changes in specimen volume resulting from the immersion test. The balance will have a capacity of 5 kilograms or more and be sensitive to 0.1 grams or less.

3.4 *Flat plate* – For very fragile specimens a supply of flat transfer plates of glass or metal will be required. One of these plates shall be kept under each of the specimens during the immersion period and during subsequent handling. Except when weighing and testing, in order to prevent breakage or distortion of the specimens.

3.5 *Testing machine* – The testing machine may be of any type of sufficient capacity that will provide a range of accurately controllable rates of vertical deformation. The rate of vertical deformation for the compression test is specified as 0.05 in (1.3 mm) per min. per 1 in. (25 mm) of height of specimen. A controllable rate of 0.2 in. (5.1 mm) per minute is required for a 4 in. (200 mm) nominal height specimen. For central control laboratory installations the testing machine shall

3 Apparatus: (continued)

conform to the requirements of Methods of Verification of Testing Machines (AASHTO T 67). The testing machine shall be equipped with two steel bearing blocks with hardened faces, one of which is spherically seated and the other plane. The spherically seated block shall be mounted to bear on the upper surface of the test specimen and the plane block shall rest on the platen of the testing machine to form a seat for the specimen. The bearing faces of the plates shall have a diameter slightly greater than that of the largest specimens to be tested. The bearing faces, when new, shall not depart from a true plane by more than 0.0005 in (0.013 mm) at any point and shall be maintained within a permissible variation limit of 0.001 in (0.025 mm). In the spherically seated block, the center of the sphere shall coincide with the center of the bearing face. The movable portion of this block shall be held closely in the spherical seat but the design shall be such that the bearing face can be rotated freely and tilted through small angles in any direction.

4 Test Sample:

4.1 At least four 4 x 4 inch (100 x 100 mm) cylindrical specimens (nominal dimension) shall be made for each test. The procedure described in Fabricating Specimens for Compressive Strength of Bituminous Mixture, MT-323, shall be followed in preparing the loose mixtures and in molding and curing the test specimens.

5 Procedure:

5.1 Allow each set of test specimens to cool for at least two hours after removal from the curing oven described in MT-323. Determine the Bulk Specific Gravity of random specimen from Group 2 in accordance with the procedures and calculation for Bulk Specific Gravity of Compacted Bituminous Mixture in Section 5.

5.2 Sort each set of four specimens into two groups of specimens. Prepare the specimens in group 1 as described in 5.2.1 and prepare the specimens in group 2 as described in 5.2.2.

5.2.1 Group 1 – Bring the test specimens to the test temperature, 77 ± 2 °F (25 ± 1 °C), by storing them in an air bath maintained at the test temperature for not less than 4 hours then determine their compressive strengths.

5.2.2 Group 2 – Immerse the test specimens in water for 24 hr. at 140 ± 2 °F (60 ± 1 °C). Transfer them to a second water bath maintained at 77 ± 2 °F (25 ± 1 °C) for 2 hr. and then immediately determine their compressive strengths.

5.3 To determine the compressive strength of the specimens place the specimens in axial compression without lateral support loading the specimens at a rate of 0.2 inches (5.1 mm) per minute. The specimen is loaded at the above rate until failure occurs. The point of failure is defined as the maximum load obtained.

6 Calculation:

6.1 Calculate the bulk specific gravity of a random test specimen from Group 2 as follows:

$$\text{Bulk specific gravity} = \frac{A}{B - C}$$

where:

A = mass of oven-dry specimen in air, g.

B = mass of surface-dry specimen in air, g.

C = mass of specimen in water, g

6 Calculation: (continued)

6.2 Calculate the maximum compressive strength of each specimen in pounds per square inch (psi) for a 4 inch (100 mm) diameter specimen as follows:

Maximum compressive strength, psi = $\frac{A}{B}$

Where:

A = the maximum load obtained for specimen in pounds.

B = area of surface loaded in inches squared. For a 4-inch (100 mm) nominal diameter specimen, it is 12.5664 inches squared.

6.3 Calculate the numerical index of resistance of bituminous mixtures to the detrimental effect of water as the percentage of the original strength that is retained after the immersion period. It shall be calculated as follows:

Index of retained strength, $\% = \frac{S_2}{S_1} x100$

Where:

S_1 = average compressive strength of dry specimens (group 1), and

S_2 = average compressive strength of immersed specimens (group 2).

7 Report:

7.1 The report shall include a random bulk specific gravity, the maximum compressive strengths for each specimen, and the percent of retained compressive strength as calculated in Sec 6.3. The report will also include the penetration range of the asphalt cement, the refinery where the asphalt was made, the percent of asphalt used and the mixing temperature of the test specimens.

8 Precision:

8.1 Single-Operator Precision – The single-operator standard deviation has been found to be 6 percent (see Note 1). Therefore, results of two properly conducted tests by the same operator on the same material should not differ by more than 18 percent (see Note 1).

Note 1 - These numbers represent, respectively the (1S) and D2S) limits as described in AASHTO Recommended Practice R4, for preparing Precision Statements for Test Methods for Construction Materials.

8.2 Multilaboratory Precision – The multilaboratory standard deviation has been found to be 18 percent (see Note 1). Therefore, results of two properly conducted tests from two different laboratories on identical samples of the same material should not differ by more than 50 percent (see Note 1).

METHODS OF SAMPLING AND TESTING
MT 325-04
METHOD OF DETERMINING MOISTURE CONTENT OF BITUMINOUS MIXTURES OR AGGREGATE USING MICROWAVE OVENS

1 Scope:

1.1 This method provides a procedure for determining the amount of moisture in either bituminous mixtures or graded aggregates used in bituminous mixtures. Its primary purpose is to provide a rapid field test to permit production control of bituminous mixtures. Its use is limited to asphalt mixtures consisting of paving grades of asphalt.

2 Referenced Documents:

AASHTO:
M 231 Weighing Devices Used in the Testing of Materials

MT Materials Manual:
MT-201 Sampling Roadway Materials
MT-202 Sieve Analysis of Fine and Coarse Aggregate
MT-303 Sampling Bituminous Paving Mixtures
MT-309 Reducing Samples of Hot Mix Asphalt to Testing Size
MT-322 Quantitative Extraction of Bituminous Mixtures
MT-417 Reducing Field Samples to Testing Size

3 Apparatus:

3.1 *Microwave* - oven capable of holding 4000-gram sample.

3.2 *Sample containers* - capable of holding 600 grams (must be Pyrex, glass, porcelain or ceramic.

3.3 *Balance* - with a 16,000-gram capacity and sensitive to 0.1 gram and conforming to the requirements of M 231.

3.4 *Spatula* - with a stainless steel blade, 7/8 inches wide by 4 inches long.

3.5 *Asbestos gloves.*

3.6 *Airtight container* - capable of holding the 2500 to 3000 gram sample.

3.7 *Fluorescent tube* - F4T5/CW (Westinghouse) or equivalent.

3.8 *600 ml. beaker.*

3.9 *Flat pan* - approximately 25 x 20 x 3 inches.

4 Sample Preparation:

4.1 Obtain 2500 to 3000 grams of bituminous mix (according to MT-303) or aggregate (according to MT-201).

4.2 Quarter the aggregate into two 500 ± 50 gram samples. Aggregate samples will be reduced in size according to MT-417.

4 **Sample Preparation:** (continued)

4.3 Bituminous mixtures will be reduced in size according to MT-309, Method B, to two 500 ± 50 gram samples.

5 **Procedure:**

5.1 Place 600-ml beaker filled with water in microwave oven, keep beaker at least half full at all times. This prevents the microwave-heating element from being damaged.

5.2 Place samples in tared paper plates or glass containers, and weigh to the nearest 0.1 gram.

5.3 Put samples in microwave oven and turn oven on.

5.4 After 10 minutes, turn the oven off, remove the containers and samples, weigh the samples and containers to the nearest 0.1-gram, and record these weights.

5.5 Place samples and containers back in the oven. Turn oven on, and dry samples for 5 more minutes.

5.6 Remove samples and containers from oven, weigh to the nearest 0.1-gram, and record weights.

5.7 Repeat steps 5.5 and 5.6 until a constant weight is obtained.

Note 1- In most cases, with moisture contents of 1.0% or less, a 10-minute drying period is sufficient.

6 **Calculations:**

6.1 After a constant weight has been obtained, calculate the moisture content of the samples as follows:

Percent of Initial Moisture $= \frac{Mi - Mf}{Mi} x100$

Where - *M* = % Moisture

Mi = initial, moist mass

Mf = final, dry mass

Example - *Mi* = 541.2g

Mf = 536.0g

Moisture Content = $\frac{541.2g - 536.0g}{541.2g} \times 100 = 0.961$, say 0.96%

6.2 If the moisture contents of the two samples differ by more than 0.2%, the test is invalid. In this case new samples must be prepared and the test rerun.

6.3 Record the moisture content as the average of the two samples.

7 **Precautions:**

7.1 Check the microwave oven daily for leakage by passing the small fluorescent tube around the entire outside surface with the oven on (keep tube 1" (2.54 cm) or less from surface). Any lighting of the tube indicates leakage. The oven should not be used until this leakage is corrected, as the

7 **Precautions:** (continued)

microwave radiation may be injurious.

7.2 Use gloves for handling hot mixtures during quartering and when placing in or removing from oven.

7.3 Do not use metal containers in oven at any time. Damage to the oven will occur.

7.4 Do not delay getting sample into oven after sampling. (If a delay of 15 minutes or more is anticipated, samples must be placed into and kept in sealed containers. For reliable results, all samples should be tested within 1 hour of sampling).

7.5 When weighing samples, do so as quickly as possible to avoid error in the balance due to heat transfer.

7.6 Plastic and paper are good microwave transmitters but may be burned due to the heat from the glass plate in the microwave.

7.7 It is recommended that at least the first sample dried of each specific type of material be constantly monitored for unusual behavior or phenomenon.

METHOD OF SAMPLING AND TESTING
MT 326-04
METHOD OF SAMPLING AND TESTING TO DETERMINE THE PLANE OF FAILURE IN RUTTED ASPHALT PAVEMENTS
(Montana Method)

1 Scope:

1.1 This method covers the procedure for obtaining and testing asphalt pavement cores in order to determine the Plane of Failure. The Plane of Failure is defined as the depth at which the voids in the wheel path and/or between the wheelpath are comparable to the voids in the passing lane.

2 Referenced Documents:

2.1 *MT Materials Manual*
MT-314 – Method of Test for Bulk Specific Gravity of Compacted Bituminous Mixtures.
MT-321 – Procedure for Determining Maximum Specific Gravity of Bituminous Paving Mixtures – "Rice Method".

3 Apparatus:

3.1 *Diamond saw*

3.2 *Coring machine*

4 Sampling:

4.1 One set of eight cores shall be taken, as shown in Fig. 1, from each area to be evaluated. Four cores consisting of one core from each wheel path, one from between the wheel paths and one from the passing lane shall be used to determine the bulk specific gravity. The other four shall be taken as close as possible to the first four and will be used to determine the voids by Rice Gravity.

4.2 In determining the Plane of Failure in rutted asphalt pavements, it is necessary that rut measurements be taken. Measurement shall be adjacent the cores taken as described in paragraph 5.1 and 5.2. *See* Note 1.

Note 1 - Whenever the void analysis does not provide sufficient information on which to base a recommendation, rut measurements serve as an aid in making recommendations for the depth of milling in rutted pavements.

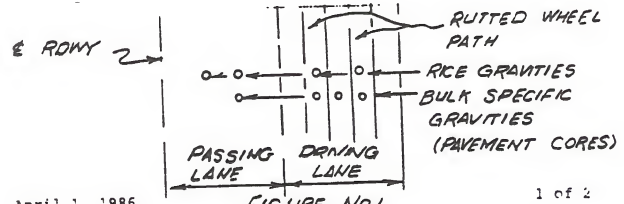


FIGURE NO.1

April 1, 1986

1 of 2

5 Sampling Frequency:

5.1 The following is only a guideline for field personnel to follow and it may be necessary to increase or decrease sampling frequencies depending on the conditions of the pavements to be studied.

5.1.1 Uniformly rutted pavements shall have three randomly selected areas evaluated by taking one set of cores as in paragraph 4.

5.1.2 Non-uniformly rutted pavements shall have three sets of cores sampled so that the appropriate cores within a group are taken from rutting with approximately the same depth.

6 Procedure:

6.1 The lifts in each core are separated, if necessary, by cutting with a diamond saw. (Note 2)

Note 2 – It may be necessary to cut the lifts in half to determine the depth of failure within a lift.

6.2 The bulk specific gravity is determined according to MT-314 for the lifts of four of the cores. (Fig. 1)

6.3 All corresponding lifts are combined for each lane and the Rice Gravity is determined according to MT-321 for each lift and in each lane.

7 Calculations:

7.1 The Rice Gravity value for each lift in each lane is used with the Bulk Specific Gravity for the corresponding lift and lane to determine the voids in that lift for a particular core. The formula is shown below.

$$\frac{A-B}{A} x100$$

where:

A – Rice Gravity

B – Bulk Specific Gravity

7.2 The voids in the wheel paths, between the wheel paths and in the passing lane, are comparable when the variation is less than 0.4%. This value is based on a limited set of data and is subject to change. It is expected that variations may not fall within the area of 0.4% and in these instances evaluations must be based on consistent results and sound judgment.

METHOD OF SAMPLING AND TESTING
MT 327-04
MECHANICAL ANALYSIS OF EXTRACTED AGGREGATE
(Modified AASHTO T 30)

1 Scope:

1.1 This method of test covers a procedure for the determination of the particle size distribution of fine and coarse aggregates extracted from bituminous mixtures, using sieves with square openings.

2 Referenced Documents:

2.1 ***MT Materials Manual:***
MT-303 - Sampling Bituminous Paving Mixtures
MT-322- Method of Test for Quantitative Vacuum Extraction of Bituminous Mixtures
MT-405 - Sieves for Testing Purposes
MT-417 - Reducing Field Samples to Testing Size

3 Apparatus:

3.1 *Balance* - The balance or scale shall have a capacity commensurate with the size of the sample being tested. The balance or scale used for weighing coarse material (plus 4 mesh) shall have a sensitivity of 0.1 pounds or 50 grams. The balance or scale used for weighing fine material (minus 4 mesh) shall have a sensitivity of 0.005 pounds (2.25 grams) for Central Laboratory testing and a sensitivity of 0.01 (4.5 grams) for job-site testing.

3.2 *Sieves* - The sieves with square openings shall be mounted on substantial frames constructed in a manner that will prevent loss of material during sieving. Suitable sieve sizes shall be selected to furnish the information required by the specifications covering the material to be tested. The sieves shall conform to the requirements of MT-405, Wire Cloth Sieves for Testing Purposes.

3.3 *Container* - A container sufficient to contain the sample covered with water and to permit vigorous agitation without inadvertent loss of any part of the sample or water. The container used shall be approved by the District or Area Materials Supervisor prior to use. (A suggested container would have a rounded bottom with a diameter of approximately 8 inches and a height of approximately 6 inches.)

3.4 *Oven* - The oven shall be capable of maintaining a uniform temperature of 230 ± 9°F (110 ± 5°C).

4 Sample:

4.1 The sample shall consist of the entire lot or sample of aggregate obtained according to Sections 3, 4 and 5 of MT-322, Test for Quantitative Extraction of Bitumen from Bituminous Paving Mixtures from which the bituminous material has been extracted. (Note 1)

Note 1 - A sample that is overloading screens will have to be split or quartered in accordance with MT-417, Reducing Field Samples to Testing Size, and graded separately and the weights combined to obtain a representative gradation.

5 Procedure:

5.1 The sample shall be dried until further drying at 110 ± 5°C (230 ± 9°F) does not alter the weight 0.1 percent, the precision of weighing. The total weight of aggregate in the bituminous mixture being tested is the sum of the weights of the dried aggregates and the mineral matter contained in the extracted bitumen. The latter is to be taken as the sum of the weight of ash in the extract and the increase in weight of the filter element as determined in MT-322.

5.2 The test sample after being dried and weighed shall be placed in a container and covered with water. Add a sufficient amount of wetting agent (Note 2) to assure a thorough separation of the material finer than the 200 mesh from the coarser particles. The contents of the container shall be agitated vigorously and the wash water immediately poured over a nest of two sieves consisting of a 10 or 16 mesh sieve superimposed on a 200 mesh sieve. The use of a large spoon to stir and agitate the aggregate in the wash water has been found satisfactory.

Note 2 - Wetting agents may include any dispersing agent such as Calgon, Joy or other detergent, or a soap, which will promote the separation of fine material.

5.3 The agitation shall be sufficiently vigorous to result in the complete separation from the coarse particles of all particles finer than the 200 mesh sieve and bring them into suspension in order that they may be removed by decantation of the wash water. Care shall be taken to avoid, as much as possible, the decantation of the coarse particles of the sample. The operation shall be repeated until the wash water is clear.

5.4 All material retained on the nested sieves shall be returned to the container. The washed aggregate in the container shall be dried to constant weight at a temperature of 110 ± 5°C (230 ± 9°F) and weighed to the nearest 0.1 percent.

5.5 The aggregate shall then be sieved over sieves of the various sizes required by the specification covering the mixture, including the 200 mesh sieve. The weight of material passing each sieve and retained on the next and the amount passing the 200 mesh sieve shall be recorded. The summation of these various weights must check the dried weight after washing within 0.2 percent of the total weight. The weight of dry material passing the 200 mesh sieve by dry sieving shall be added to the weight of mineral matter in the bitumen and the weight removed by washing in order to obtain the total passing the 200 mesh sieve. If it is desired to check the weight of material washed through the 200 mesh sieve, the wash water may be evaporated to dryness or filtered through a tared filter paper which is subsequently dried and weighed. The weights of fractions retained on the various sieves and the total passing the 200 mesh sieve shall be converted to percentages by dividing each by the total weight of aggregate in the bituminous mixture from Section 5.1.

6 Calculations:

6.1 Plus 4 Mesh Material - The individual weights retained must be converted to total weight passing each of the various sieves. The total weight passing is then divided by the total weight of the sample, multiplied by 100, which will result in the percent passing. (See page 3 of 4 for example.)

7 Report:

7.1 The results of the sieve analysis shall be reported as the total percentages passing each sieve size and reported to the nearest whole number for all material coarser than the 200 mesh. The 200 mesh material shall be reported to one tenth of one percent. Percentages shall be calculated on the basis of the total weight of the sample, including any material finer than the 200 mesh sieve.

EXTRACTION WORKSHEET

Lab. Number:_____ Sample Number:__Example__ Date:_____

Termini:__3/4" P.M.S. Gr. B_____

BEFORE EXTRACTING

A: 1407.6 Weight of Sample

B: 160.2 Weight of Pan

C: 13.0 Weight of Filter

D: 173.2 Weight of Filter and Pan

AFTER EXTRACTING

E: 1493.7 Weight of Sample, Pan, and Filter

F: 1493.7 - D: 173.2 = F: 1320.5 Weight After Extracting

A: 1407.6 - F: 1320.5 = G: 87.1 Weight of Asphalt

G: 87.1 (100) = H 6.19 Percent of Asphalt
F + G 1320.5 + 87.1

Before Wash 1320.5 After Wash 1220.6 LBW. 99.9

Wt. Retained		Wt. Pass.	Percent
	1"		
--	3/4" 1320.5	100	
57.4	1/2" 1263.1	96	
219.0	3/8" 1044.1	79	
359.7	4M 684.4	52	
225.7	10M 458.7	35	
169.6	40M 289.1	22	
189.2	200M 99.9	7.6	

Remarks:

All weights are in grams.

Percent of asphalt by total weight of mix.

METHODS OF SAMPLING AND TESTING
MT 329-04
PROCEDURE FOR EVALUATING PLANT MIX SURFACING FAILURES

1 Scope:

1.1 This method covers the step-by step procedure for evaluating a plant mix surfacing failure. The procedure calls for reviewing the types of plant mix failures and method for rating the distressed areas.

1.2 After determining the type and extent of the failure, further investigational requirements will include reviewing plant mix production records, visual analysis, deflection analysis, sampling analysis of plant mix, base and subgrade materials and surfacing design analysis. Based upon all the information and data gathered through this procedure, the causes, potential solutions and recommendations to correct the plant mix surfacing failures can be determined.

2 Visual Analysis:

2.1 The first step in investigating a pavement failure is to perform a complete and comprehensive visual analysis of the entire project emphasizing the distressed areas in question.

2.2 Determine the approximate milepost and/or stationing and length of each of the distressed areas. The following is a list of pavement distress types and a rating system to be used for the distress.

PAVEMENT FAILURE RATING SYSTEM
RATING

FAILURE TYPE Rutting	Light	Moderate	Severe
Rut Depth Rate of Rutting Lateral Movement Of Rut (Humping)	0-1/2" 0-1/8"/yr. None Visible	1/2 – 3/4" 1/8 – 3/8"/yr.	3/4" & Greater 3/8" yr.& Greater Visible Bulge
Cracking	Longitudinal Cracks In wheel paths (Load Associated)	Alligator or Block Cracking Tight	Alligator or Block Cracking Edges spaced – pieces loose or missing
*Stripping	Some asphalt material stripped	"Cores	"Cores
Ravelling	Fines removed from Surface.	1st layer coarse Aggregate removed	Pavement removed through one or more lifts.

*Any stripping should be noted.

"If the investigation requires plant mix cores, advanced stages of stripping will be determined at that time.

NOTE - If dual wheel ruts exist, they should be noted. Measurements should always be taken in both wheelpaths with a stringline stretched from centerline to the shoulder to obtain the measurements.

3 Report of Visual Analysis:

3.1 A summary of the visual analysis should be written immediately after the investigation.

3 Report of Visual Analysis: (continued)

3.2 The report should include date, reviewer, project termini, and detailed information concerning each distressed area. This information should include but not be limited to approximate milepost or station, length, width, relationship to centerline, lane and type of distress. Also, photographs of the typical distress on the project should be included. In addition to recording the types of pavement distress referenced above, record any other problems that are visible (drainage, terrain, frost problems, dips or swells, etc.). Based upon this visual analysis, the course of action and investigational requirements can be determined.

3.3 Copies of the report shall be sent to the District Engineer and the Materials Bureau Chief.

4 Deflection Analysis:

4.1 After the visual analysis report has been evaluated, the second step of this procedure will normally require Road Rater testing. The decision to have a Road Rate analysis will be determined based upon the visual analysis. When the decision has been made to use the Road Rater, the following are the steps that will be followed.

4.2 The Road Rater shall be used to determine the in-place strengths of each layer. An elastic modulus for each layer will be determined from the roadway deflections.

4.2.1 Deflection tests will be taken at 200-800 foot intervals throughout problem areas to determine the extent of the distress. In addition, the remainder of the project will be tested using the normal testing intervals (six tests per mile).

4.2.2 The deflection analysis will be reviewed for elastic modulus of each layer to determine the nature and extent of the problem. The required design overlay thickness analysis will then be performed.

5 Investigation Requirements:

5.1 Determine the investigational requirements depending on the type and extent of the plant mix failure. The following is a list of the distress types and requirements for each:

Distress Type	Investigation Required
Cracking – Alligator	(1)-(7)
Rutting & Shoving	(1)-(7)
Stripping – Underlying Courses	(1)-(7)
Ravelling – Surface	(1),(3),(4)
Segregation	(1),(3),(4)

6 Investigational Requirements:

6.1 Physical Data: (information already obtained)
Location
Weather
Extent of Failure
Photos

6.2 Deflection Analysis: (information already obtained)
Road Rater testing – evaluate good and bad areas of the project.

6.3 Production Records: (a review of construction reports)

NOTE - When reviewing the reports listed below, look for any abnormalities.

Example: The production records generated during construction should be reviewed to determine if any problems during construction can be related to the pavement failure. For example there may have been some density problems in the same area of the failure, late paving, etc.

Mix Design
Plant Reports
Marshall Tests
Aggregate Tests
Compaction Tests
Monitor Samples
Project Diaries

6.4 **Core Samples:** Plant mix core samples shall be obtained and tested as follows:

NOTE - Lifts will be identified and tested separately.

Tests
Thickness
Density
Rice Gravity
A.C. Content
Gradation
HP-GPC
Abson Extraction – AC Penetration
Petrographic – Geology

Other tests to be determined by the Materials Bureau at the time of testing

7 **Sampling In-Place Material:**

R Value
Liquid Limit and Plastic Index
Moisture
Gradation
Proctor

8 **Traffic Data:**

Present ADL
Accumulative ADL

9 **Structural Properties:**

Gravel Equivalency – Surfacing Design

10 **Samples and Testing Required:**

10.1 Samples shall be taken so that the following tests and procedures can be run to evaluate the problem areas. The samples will be submitted to the Materials Bureau for testing unless otherwise specified.

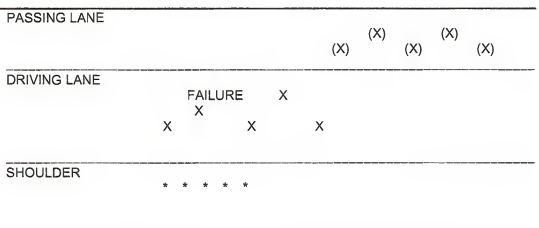
10.2 ***Plant Mix Surfacing Core Samples:***

10.2.1 Samples shall be taken of each plant mix layer with at least five 4" cores from a bad area, a shoulder next to bad area, and good area. (See Figure 1 for sampling diagram.) If more than five distressed areas exist on a project, the minimum number of sample locations will be three if all distressed areas appear to be visually identical. If material or geological conditions change between distressed areas, each various condition shall be sampled. If the lifts are still intact they shall be separated using a coring saw if required. Each lift of plant mix shall be evaluated for:

10.2 ***Plant Mix Surfacing Core Samples:*** *(continued)*

Rice Gravity
Density
Thickness – Each core should be measured
Extracted Gradation (MT-202 or MT-327)
Extracted Percent Asphalt (MT307)
Absorption Extraction – Asphalt Penetration
HP-GPC
Petrographic-Analysis

Figure 1 *Typical Coring Scheme*



X – Samples within area of visible failure
***** - Samples within same paver pass but not visibly failed
(X) – Samples from good area

10.3 Base and Subgrade:

10.3.1 When obtaining samples of the base and subgrade materials, a minimum 3-by-3-foot area of plant mix shall be taken in the wheelpath at each location. This should allow for adequate testing and sampling of each lift of material.

10.3.2 In-place densities and moisture shall be obtained for each lift using a nuclear gauge.

10.3.3 In-place moisture samples shall be taken of each lift and immediately placed in a sealable plastic sack. The sample size shall be a minimum of 1 lb. (450 grams). These samples shall then be oven dried to obtain a moisture content.

10.3.4 A minimum of two "R" value samples shall be taken from both the base and subgrade for a given problem area. In addition, one sample per mile shall be taken for the remainder of the project. The sample size will be determined in accordance with MT-207.

10.3.5 Samples and size of each lift shall be taken immediately and placed in a sealable plastic bag for soils classification (MT-214), plastic index and liquid limit (MT-208) in accordance with referenced procedures.

10.3.6 Samples of the base and subgrade shall be taken for a proctor test to establish the optimum moisture and density. The sample size shall be determined in accordance with MT-230.

11 Traffic Data:

11.1 Traffic data will be requested from the Planning and Statistics Bureau by the Materials Bureau. This data will be used by the Road Rater and Surfacing Design Sections to determine if any structural deficiencies exist. If the traffic section in the Planning Bureau feels traffic data may not reflect the true 18 Kip axle loads, a site specific investigation should be conducted by them.

12 Structural Analysis - Surfacing Design:

12.1 The surfacing Design personnel will check the design of the problem area based on the new "R" Values and the condition of the pavement structure in place.

13 Report:

13.1 A summary of the sample tests and other investigational requirements will be submitted upon completion of all testing of all testing and analysis.

METHODS OF SAMPLING AND TESTING
MT 330-04
RESISTANCE OF COMPACTED BITUMINOUS MIXTURE
TO MOISTURE INDUCED DAMAGE
(Modified AASHTO T 283)

1 Scope:

1.1 This method is intended to evaluate the effects of saturation and accelerated water conditioning of compacted bituminous mixtures in the laboratory.

2 Referenced Documents:

2.1 ***AASHTO:***
T 166 Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
T 167 Compressive Strength of Bituminous Mixtures
T 209 Teroretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
T 245 Resistance of Plastic Flow of Bituminous Mixtures by Means of Hveem Apparatus
T 247 Preparation of Test Specimens of Bituminous Mixtures by Means of California Kneading Compactor
T 269 Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
T 312 Preparing and Determining the Density of Hot-Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

ASTM:
D 2041 Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
D 3549 Thickness or Height of Compacted Bituminous Paving Mixture Specimens

3 Apparatus:

3.1 Equipment for preparing and compacting specimens from one of the following AASHTO Methods: T-245 and T-247, or ASTM Method D 3387.

3.2 *Vacuum container* - preferably Type D, and vacuum pump or water aspirator from ASTM D 2041, including manometer or vacuum gauge.

3.3 *Balance* - and water bath from AASHTO T 166.

3.4 *Water bath* - capable of maintaining a temperature of 140 + 1.8°F (60 ± 1°C).

3.5 *Freezer* - maintained at 0+ 5°F (-18 ± 3°C).

3.6 A supply of plastic film for wrapping, heavy-duty leak proof plastic bags to enclose the saturated specimens and masking tape.

3.7 10 ml graduated cylinder.

3.8 *Aluminum pans* - having a surface area of 75-100 square inches in the bottom and a depth of approximately 1 inch.

3.9 *Forced air draft oven* - capable of maintaining a temperature of 140 ± 1.8F (60 ± 1C).

3.10 *Loading jack and ring dynamometer from AASHTO T 245* - or a mechanical or hydraulic testing machine from AASHTO T167 to provide a range of accurately controllable rates of vertical deformation in 2 in. per minute (50.8 per minute).

3 Apparatus: (continued)

3.11 *Loading Strips* - If used, steel loading strips with a concave surface having a radius of the test specimen. For specimens 4 inches (102mm) in diameter the loading strips shall be 0.5 inches (12.7mm) wide, and for specimens 6 inches (152.4mm) in diameter the loading strips shall be 0.75 in. (19.05mm) wide. The length of the loading strips shall exceed the thickness of the specimens. The edges of the loading strips shall be rounded by grinding.

4 Preparation of Laboratory Test Specimens:

4.1 Specimens 4 inches (100 mm) in diameter and 2.5 inches (63.5 mm) thick are usually used. Specimens of other dimensions may be used if desired and should be used if aggregate larger and 1 inch (25.4 mm) is present in the mixture and/or is not permitted to be scalped out.

4.2 After mixing, the mixture shall be placed in an aluminum pan having a surface area of 75-100 square inches in the bottom and a depth of approximately 1 inch (25.4 mm) and cooled at room temperature for 2 ± 0.5 hours. Then the mixture shall be placed in a 140°F (60°C) oven for 16 ± 1 hour for curing. The pans should be placed on spacers to allow air circulation under the pan if the shelves are not perforated.

4.3 After curing, place the mixture in an oven at 275°F (135°C) for 2 hours prior to compaction. The mixture shall be compacted to 7 ± 0.5 percent air voids or void level expected in the field. This level of voids can be obtained by adjusting the number of blows in AASHTO T 245; adjusting foot pressure, number of tamps, leveling load, or some combination in AASHTO T 247; and adjusting the number of revolutions in ASTM D 3387. The exact procedure must be determined experimentally for each mixture before compacting the specimens for each set.

4.4 After extraction from the molds, the test specimens shall be stored for 24 ± 1 hour at room temperature.

5 Preparation of Core Test Specimens:

5.1 Select locations on the completed pavement to be sampled, and obtain cores. The number of cores shall be at least 6 for each set of mix conditions.

5.2 Separate core layers as necessary by sawing or other suitable means, and store layers to be tested at room temperature.

6 Evaluation of Test Specimens and Grouping:

6.1 Determine theoretical maximum specific gravity of mixture by AASHTO T 209.

6.2 Determine specimen thickness by ASTM D 3549.

6.3 Determine bulk specific gravity by AASHTO T 166. Express volume of specimens in cubic centimeters.

6.4 Calculate air voids by AASHTO T 269.

6.5 Sort specimens into two subsets of three specimens each so that average air voids of the two subsets are approximately equal.

7 Preconditioning of Test Specimens:

7.1 One subset will be tested dry and the other will be preconditioned before testing.

7.2 The dry subset will be stored at room temperature until testing. The specimens shall be wrapped with plastic or placed in a heavy duty leak proof plastic bag. The specimens shall then be placed in a 77 ± 1°F (25 ± 0.5°C) water bath for a minimum of 2 hours ± 10 minutes and then tested as described in Section 7.

7 Preconditioning of Test Specimens: (continued)

7.3 The other subset shall be conditioned as follows:

7.3.1 Place the specimen in the vacuum container supported above the container bottom by a spacer. Fill the container with distilled water at room temperature so that the specimens have at least one inch of water above their surface. Apply partial vacuum, such as 10 to 26 inches Hg for a short time, such as five minutes. Remove the vacuum and leave the specimen submerged in water for 5 to 10 minutes.

7.3.2 Determine bulk specific gravity by AASHTO T 166. Compare saturated surface-dry weight with saturated surface-dry weight determined in Section 5.3. Calculate volume of absorbed water.

7.3.3 Determine degree of saturation by comparing volume of absorbed water with volume of air voids from Section 5.4. If the volume of water is between 70% and 80% of the volume of air, proceed to Section 6.3.4. If the volume of water is less than 70%, repeat the procedure beginning with Section 6.3.1 using more vacuum and/or time. If volume of water is more than 80%, specimen has been damaged and is discarded. Repeat the procedure beginning with Section 6.3.1, using less vacuum and/or time.

7.3.4 Cover the vacuum saturated specimens tightly with a plastic film (saran wrap or equivalent). Place each wrapped specimen in a plastic bag containing 10 ml of water and seal the bag.

7.3.5 Place the plastic bag containing specimen in a freezer at 0 ± 5°F(-18 ± 3°C) for a minimum of 16 ± 1 hour.

7.3.6 After removal from the freezer, place the specimens into a 140 ± 1.8°F(60 ± °C) water bath for 24 ± 1 hours. As soon as possible after placement in the water bath, remove the plastic bag and film from the specimens.

7.3.7 After 24 ± 1 hours in the 140°F(60°C) water bath, remove the specimens and place them in a water bath already at 77 ± 1°F(25 ± 0.5°C) for 2 hours ± 10 minutes. It may be necessary to add ice to the water bath to prevent the water temperature from rising above 77°F(25°C). Not more than 15 minutes should be required for the water bath to reach 77°F(25°C). Test the specimens as described in Section 7.

8 Testing:

8.1 Determine the indirect tensile strength of dry and conditioned specimens at 77°F(25°C).

8.2 Remove the specimen from 77°F(25°C) water bath and place between the two bearing plates in the testing machine. Apply the load to the specimen by means of the constant rate of movement of the testing machine head of 2 inches (50.8 mm) per minute.

Note - When reviewing a failure or stripped pavement, the temperature of the conditioned specimens in 7.1 and 7.2 of 77°F (25°C) should be changed to 55°F(13°C).

8.3 If steel loading strips are used, record the maximum compressive strength noted on the testing machine and continue loading until a vertical crack appears. Remove the specimen from the machine and pull apart at the crack. Inspect the interior surface for stripping and record the observations.

8.4 If steel loading strips are not used, stop loading as soon as the maximum compressive load is reached. Record the maximum compressive load. Remove the specimen, measure and record the side (edge) flattening to the nearest 0.1 inch. The flattening may be easier to measure if the flattened edge is rubbed with the lengthwise edge of a piece of chalk. After recording the flattening, replace the specimen in the compression machine and compress until a vertical crack appears. Remove the specimen from the machine and pull apart at the crack. Inspect the interior surface for stripping and record the observations.

9 Calculations:

9.1 If steel loading strips are used, calculate the tensile strength as follows:

$$S_t = -\frac{2P}{\pi\, tD}$$

where:

S_t = tensile strength, psi

P = maximum load, psi

t = specimen thickness, inches

s = specimen diameter, inches

9.2 If steel loading strips are not used, calculate the tensile strength of a 4-inch (102mm)-diameter specimen as follows:

$$S_t = \frac{S_{10}P}{10{,}000\, t}$$

where:

S_t = tensile strength, psi

S_{10} = maximum tensile stress corresponding to the width of flattened area from Table 1

P = maximum load, pounds

t = specimen thickness, inches

9.3 Express the numerical index of resistance of asphalt mixtures to the detrimental effect of water as the ratio of the original strength that is retained after the freeze-warm water conditioning.

Tensile Strength Ratio (TSR) $\frac{S_2}{S_1}$

where:

S_1= average tensile strength of dry subset, and

S_2= average tensile strength of conditioned subset.

TABLE 1

Maximum Tensile Stress (S) for a base index of a 10,000 lb. Load, 4" diameter specimen, 1 inch in length

Width of Flattened Area, In Inches	Maximum Tensile Stress,S. PSI
0.0	1640
0.1	1629
0.2	1619
0.3	1606
0.4	1595
0.5	1571
0.6	1540
0.7	1508
0.8	1470
0.9	1438
1.0	1405

METHOD OF SAMPLING AND TESTING
MT 331-04
METHOD OF SAMPLING AND EVALUATING
STRIPPING PAVEMENTS
(Montana Method)

1 Scope:

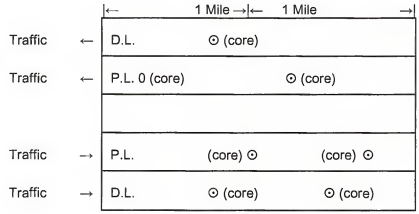
1.1 This method describes the procedure for sampling and evaluating asphalt pavements that are suspected of stripping.

2 Sampling Procedure:

2.1 4-Lane Roadway:

2.1.1 A minimum of 2 cores per mile of roadway, of which 1 core will be taken in the outside wheelpath of the driving lane and the other core in the passing lane.

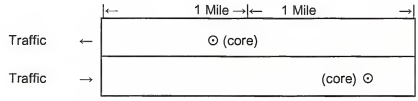
Example



2.2 2-Lane Roadway

2.2.1 A minimum of 1 core per mile of roadway, of which each core will be taken in the outside wheelpath and in alternating lanes.

Example



2.3 Cores should represent the pavement for the proposed project. Depending upon pavement condition, it may be necessary to modify the sampling frequency and location.

2.4 The exact locations of the cores within the 1 mile section should be determined by a random method.

3 Sample Identification:

3.1 Cores are to be marked for identification. If cores are not intact, rubble from the field has no useful purpose and should not be submitted. Field notes should be kept describing the appearance of the core. Describe where the intact portion was on the core; top, middle or bottom of the plant mix and submit it for stripping evaluation. Also describe the roadway condition and any other information that would be helpful in evaluating the cores and the in-place pavement.

4 Submitting of Samples:

4.1 The cores are to be submitted to the Materials Bureau for evaluation. Each core is to be accompanied by a completed Form 31. Observations and comments should be included on the Form 31.

5 Evaluation of Cores

5.1 Procedure:

5.1.1 The total core should be evaluated for stripping using the "control photographs" developed by the Materials Bureau. Split cores by indirect tensile loading in a press. Evaluate each lift or distinct layer of plant mix for stripping using the numeric rating system that corresponds to the reference photographs provided by the Materials Bureau.

5.1.2 Extract asphalt and do an abson recovery from a composite sample of plant mix from four complete cores. Determine the viscosity of this asphalt. This value is used in the Road Rater back calculation of Resilient Modulus.

6 Reporting Results:

6.1 At the completion of the evaluation, a report will be written by the Materials Bureau with test results and recommendations concerning extent of stripping, removal of stripped material and other test information. The report should evaluate each lift of plant mix for stripping.

METHODS OF SAMPLING AND TESTING
MT 332-04
GYRATORY COMPACTION OF BITUMINOUS MIXTURES
(*MONTANA TEST METHOD*)

1 Scope:

1.1 Verification of asphalt content and mixture properties of bituminous mixtures by the compaction of cylindrical specimens of hot mix asphalt (HMA) using the Superpave gyratory compactor. The density of bituminous mixtures is determined directly for Ndesign.

2 Referenced Documents:

2.1 ***AASHTO:***
M 231 Weighing Devices Used in the Testing of Materials
PP 48 Evaluation of the Superpave Gyratory Compactors (SGC) Internal Angle of Gyration

MT Manual:
MT-314 Method of Test for Bulk Specific Gravity of Compacted Bituminous Mixtures
MT-321 Procedure for Determining Maximum Specific Gravity of Bituminous Paving Mixtures – "Rice Method"

3 Process Description:

3.1 It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

3.2 A sample is placed into a 150 mm mold for an apparatus that compacts bituminous mixture using a combination of pressure and gyration. The apparatus measures the specimen height very precisely as compaction occurs after each gyration. The required compaction effort is defined from tables found in the specifications. This procedure is intended to show how closely the bituminous mixture being produced is to the production requirements.

4 Significance and Use:

4.1 This procedure is used to prepare specimens for determining the volumetric properties of HMA.

5 Apparatus:

5.1 *Superpave Gyratory Compactor* - An electrohydraulic or electromechanical compactor with a ram and ram heads as described in Section 5.3 that are restrained from revolving during compaction. The axis of the ram shall be perpendicular to the platen of the compactor. The ram shall apply and maintain a pressure of 600 ± 18 kPa perpendicular to the cylindrical axis of the specimen during compaction. The compactor shall tilt specimen molds at an average internal angle of 1.16 ± 0.02 degrees (Note 1). The equipment shall gyrate specimen molds at a rate of 30.0 ± 0.5 gyrations per minute throughout compaction.

Note 1 – For most equipment this equates to an external angle of 1.25 ± 0.02 degrees.

5.1.1 *Specimen Height Measurement and Recording Device* - When specimen density is to be monitored during compaction, a means shall be provided to continuously measure and record the height of the specimen to the nearest 0.1 mm during compaction; once per gyration.

5 Apparatus: (continued)

5.1.2 The system may include a printer connected to an RS232C port capable of printing test information, such as specimen height per gyration. In addition to a printer, the system may include a computer and suitable software for data acquisition and reporting.

5.2 *Specimen Molds* - Specimen molds shall have steel walls that are at least 7.5 mm thick hardened to at least Rockwell C48. The inside of the molds shall be smooth (Note 2). Molds shall have an inside diameter of 149.90 to 150.00 mm and be at least 250 mm high at room temperature.

Note 2 - Smooth is measured in accordance with ANSI B46.1 with rms value of 1.60 µm or less.

5.3 *Ram Heads and Mold Bottoms* - Ram heads and mold bottoms shall be fabricated from steel with a minimum Rockwell hardness of C48. The ram heads shall stay perpendicular to its axis. The platten side of each mold bottom shall be flat and parallel to its face. All ram and base plate faces (the sides presented to the specimen) shall be flat to meet smoothness requirement in 5.2 (Note 2) and shall have a diameter of 149.50 to 149.75 mm.

5.4 *Thermometers* - Armored, glass, thermal reading or dial-type thermometers with metal stems for determining temperature of aggregates, asphalt and asphalt mixtures between 10° C to 232° C.

5.5 *Balance* - a balance meeting the requirements of M231, Class G5, for determining the mass of aggregates, binder and HMA.

5.6 *Oven* - An oven, thermostatically controlled to ± 3° C, for heating aggregates, binder, HMA and equipment as required. The oven shall be capable of maintaining the compaction temperature range.

5.7 *Miscellaneous* - flat bottom metal pans of at least 500 square inches that are square or rectangular for heating plant mix and that will accommodate quartering. Scoop to remove mixture quarters for testing. Large spatula for turning and mixing sample prior to quartering. "Insulated gloves, a lab apron or coat and other safety equipment as necessary. Lubricating materials recommended by compactor manufacturer and assorted cloth and paper rags for wiping molds and other surfaces. A Gyro Loader (a trough) is optional for adding samples to the mold.

6 Standardization:

6.1 Items requiring periodic verification of calibration include the ram pressure, the angle of gyration, the gyration frequency, the LVDT (or other means used to continuously record the specimen height) and oven temperature. Verification of the mold and platen dimensions are also required. When the computer and software options are used, periodically verify the data processing system output using a procedure designed for such purposes. Verification of calibration, system standardization and quality checks may be performed by the manufacturer, other agencies providing such services, or in-house personnel. **Frequency of verification shall follow manufacturer's recommendations.**

6.2 The angle of gyration may refer to either the external angle (tilt of mold with respect to a plane external to the gyratory mold) or the internal angle (tilt of the mold with respect to end plate surface within the gyratory mold). Procedures used to verify the calibration of the angle of gyration must be appropriate for measuring the angle desired.

Note 3 – The two methods (Method A – external and Method B – internal) of verifying the calibration of the gyration angle should NOT be considered equivalent. The gyration angle for all SGCs in a group for which compaction results are to be compared should be verified using the same method.

6.2.1 *Method A* – The calibration of the external angle of gyration should be verified using the manufacturer's recommendations for the appropriate SGC

6.2.2 *Method B* – The calibration of the internal angle of gyration should be verified in accordance with AASHTO PP 48.

7 Materials:

7.1 Approximately 22,000 grams of plant mix are required to perform all of the required tests, including fabrication of two gyratory specimens.

8. Preparation of Apparatus:

8.1 Lubricate any surfaces as required by the Manufacturer.

8.2 Turn on the main power for the compactor for the manufacturer's required warm-up period. Verify machine settings are correct for angle, pressure and number of gyrations.

Note 4 - The required number of gyrations are shown in the Special Provisions.

8.3 Turn on the device for measuring and recording the height of the specimen and verify that the readout is in the proper units, mm, and that the recording device is ready and, if used, prepare the computer to record the height data and enter the header information for the specimen.

9 Asphalt Specimen Fabrication:

9.1 The batch weights will be adjusted to result in a compacted specimen having dimensions of 150 mm in diameter and 115 ± 3 mm in height at the designed number of gyrations. Plant mix that is brought to the test location and is still within the compaction temperature range may be batched for immediate testing. Loose HMA plant mix below the compaction temperature range shall be brought to the compaction temperature range by careful uniform heating in an oven immediately prior to molding. Heating proceeds more quickly if the sample is placed in a clean (buttered) flat bottomed pan. Loose mix that is at a temperature within the compaction temperature range should not be reheated.

10 Compaction Procedure:

10.1 Place a compaction mold and base plate in an oven at the required compaction temperature for to pre-heat mold and base plate to compaction temperature prior to the estimated beginning of the compaction cycle. When the bituminous mixture is within the compaction temperature range, remove the heated mold and base plate from the oven and place a paper disc in the bottom of the mold.

Note 5 – It is recommended to compact test specimens at a constant temperature.

10.2 Pour the pre-weighed quantity of bituminous mixture into the mold in one lift. The use of the gyro loader will facilitate this operation. If you do not have a gyro loader, another method that has worked is to pour the sample from a paper bag that has been filled with proper weight of bituminous mixture. The bag acts as a container and a funnel when filling the mold. Care should be taken to avoid segregation. Dump, don't trickle, the sample into the mold. Level the mix with the stroke of a spatula and place another paper disk on top of the leveled material. If using the Pine compactor, the top plate is inserted with the bevel up. See the operating manual for the equipment you have for more detailed instructions or another brand of compactor.

10.3 Center the mold under the loading ram. With the Pine machine, rotate the mold clockwise to the stop. Start the load compaction cycle. The machine will lower the ram until the pressure on the specimen reaches 600 kPa ± 18 kPa, apply a 1.25 ± 0.02° external angle to the mold assembly and begin the gyratory compaction.

10.4 Allow the compaction to proceed until the desired number of gyrations is reached and the ram retracts. Record the specimen height at Ndes. A printed record may be produced as the compactor operates. Remove the mold from the compactor and extrude the specimen from the mold.

10 Compaction Procedure: (continued)

Note 6 - Specimens may usually be extruded from the mold immediately. For lean, rich or tender mixtures, a cooling period of 5 to 10 minutes may be necessary before extruding the specimen to avoid having the specimen crumble.

10.5 Remove the paper disks from the top and bottom of the specimens. Write the specimen number on the specimen and on the gyration log sheet. Cool the specimens by placing them ahead of a fan or an air conditioner. Handle them carefully. Hot specimens are fragile.

Note 7 - Before reusing the mold, place it in an oven to reheat to compaction temperature range. The use of multiple molds will speed up the compaction process.

11 Density Procedure:

11.1 Determine the maximum specific gravity (G_{mm}) of the loose mix in accordance with MT-321 using a companion sample. The companion sample shall be aged to the same extent as the compaction sample.

11.2 Record the mass of the extruded specimen to the nearest 0.1 gram and determine the bulk specific gravity (Gmb) of the extruded specimen in accordance with MT-314. This is the bulk gravity of the specimen at Ndes. Measure the bulk density of the compacted bituminous mixture after the specimen has cooled sufficiently (slightly warm to touch, not hot) following MT-314.

% Air Voids (Va) Record and round to the nearest 0.1%.

$$Va = 100x\left(\frac{Gmm - Gmb}{Gmm}\right)$$

Gmm = maximum specific gravity of paving mixture (Rice)
Gmb = bulk specific gravity of compacted mixture

Voids in the Mineral Aggregate (VMA) Record and round to the nearest 0.1%.

$$VMA = 100 - \left(\frac{Gmb(100 - \%AC)}{Gsb}\right)$$

Voids Filled with Asphalt (VFA) Record and round to the nearest 1.0%.

$$VFA = 100x\left(\frac{VMA - Va}{VMA}\right)$$

Dust/Asphalt Ratio Record and round to the nearest 0.1%.

$$\frac{-200\%pass(MT-320)}{CorrectedAsphaltContent(MT-319)} = _____$$

Note 8 – The Dust/Asphalt ratio is to be used during mix design and field production.

11 Density Procedure:

Dust Proportion Record and round to the nearest 0.1%.

Effective Asphalt Content:

$$Pbe = -(PsxGb)x\frac{(Gse - Gsb)}{(GsexGsb)} + Pb _____ estimated$$

Pbe = effective asphalt content, percent by total mass of mixture
Ps = aggregate content, percent by total mass of mixture
Gb = specific gravity of asphalt
Gse = effective specific gravity of aggregate
Gsb = bulk specific gravity of aggregate
Pb = asphalt content, percent by total mass of mixture

Note 9 – The Dust Proportion is to be used during mix design.

Link to Excel spreadsheet

Form No. F400 B Q:\MT-STD\F400.doc
Revised 03/12/02 - BJB

GYRATORY DATA ENTRY FORM

Project No._____ Project Name_____

Date_____ Operator_____ Title_____

Project _____ Mix Design Number_____ Design Date_____

Bin %: Coarse_____ Intermediate _____ fine_____

Bulk gravity of Coarse_____ Intermediate _____ Fine _____ Bulk gravity of Blend_____

Source of AC _____ Grade of AC_____ Gravity of AC_____

Sample No.									AVGS.
% AC (spot check)									
Plant temperature									
Time sampled									
Mix temperature									
Time Tested									
Mass									
Height Ini. (H) i									
Height Des. (H) d									
Wt. In Air (a)									
Wt. In Water (c)									
SSD Wt. In Air (b)									

Gravities
AVGS

Rice (Gmm.)									
Dsgn Bulk (Gmb) =a/(b-c)									
Initl Bulk (Ini Gmb) = Gmb x (H)d /(H)i									

Voids:
AVGS

Dsgn.Vds (Va). = 100 – (Gmb/Gmm) x 100.									
Ini. Vds.=100– ini Gmb x 100 / Gmm									
VMA =100 –(Gmb) X 100 / Gmm									
VFA =100 –(VMA - Va)X100 / VMA									

Notes:

_____

_____

DISTRIBUTION: _____ Matls. Bureau _____ Constr. Bureau _____ Distr. Lab,_____ Area Lab, _____ Constr File, _____ F.P.M.

METHODS OF SAMPLING AND TESTING
MT 333-04
METHOD OF TEST FOR THE TORSIONAL RECOVERY OF LATEX MODIFIED ASPHALT EMULSION RESIDUE

1 Scope:

1.1 This test method provides an indication of the amount of elasticity that has been imparted to asphalt by the addition of latex. The asphalt used in this test has been recovered from an emulsion.

2 Apparatus:

2.1 *Sample container* – A flat-bottomed, cylindrical, seamless tin 55mm (2.17 inch) in diameter and 35 mm (1.38 inch) in depth. The container is commonly known as a 3-ounce ointment tin.

2.2 *Disc and spider assembly* – This assembly is shown in figure 1. The disc is made of aluminum. The spider assembly, bolt, and pointer are made of steel.

2.3 *Wrench* – A 9/16 inch open-end or box wrench.

2.4 *Timer* – A stopwatch, clock, or other timing device graduated in divisions of one second or less.

2.5 *Scale* – A paper scale, graduated in millimeters, at least 180 mm in length.

3 Procedure:

3.1 Place the spider assembly on the container and adjust it so that it is centered, using the small nuts on the arms of the spider to maintain the adjustment. Adjust the depth of the disc in the container so that the top of the disc will not be below the surface of the asphalt. Remove the spider assembly from the container. Construct two, centered spider assemblies and containers per test.

3.2 Obtain a latex modified asphalt residue sample by following the procedure outlined in AASHTO T-59, Residue By Evaporation, sections 21 – 27.

3.3 Transfer a sufficient quantity of the hot residue into the sample container to fill it to within ½ to ¼ inch from the top of the container. Immediately place the previously centered spider assembly on the container and adjust the depth of the disc to bring the top of the disc level with the surface of the asphalt.

3.4 Place the two test assemblies in a 138°C (280°F) oven for ten minutes to allow air bubbles to escape and the break the surface tension around the disc. Remove the assembly from the oven and allow to cool to room temperature for two hours.

3.5 Tape a paper scale around the container and mark the location of the pointer. Make another mark 180° form the pointer (halfway around the container).

3.6 Holding the container and spider assembly rigidly, place the wrench on the bolt head and turn the bolt to the 180° reference mark and release immediately. The rotation should be done at a steady rate and be accomplished in approximately 5 seconds. Start the stopwatch when the bolt is released. Mark the location of the pointer on the scale when 30 seconds have elapsed, and again when 30 minutes have elapsed. Repeat the procedure with the second test assembly.

4 Calculation and report:

4.1 The percent of recovery following deformation is calculated as follows:

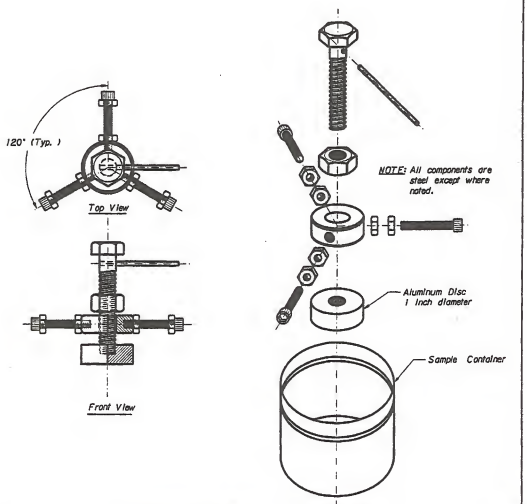
Percent Recovery = *100[A/(B/2)]*

where:

A = The arc on the container, measured in millimeters, between the mark made after 30 seconds has elapsed, and the mark made after 30 minutes has elapsed.

B = The circumference of the can, measured in millimeters.

4.2 Report the percent recovery as an average of the two tests.



SPIDER ASSEMBLY
Scale ~ N. T. S.

MONTANA DEPARTMENT OF TRANSPORTATION

FILENAME: Material.dgn | 5-3-00 | D.D.S.

METHODS OF SAMPLING AND TESTING
MT 334-04
METHOD OF TEST FOR HAMBURG WHEEL-TRACK TESTING OF COMPACTED BITUMINOUS MIXTURES

1 Scope:

1.1 Use this test method to determine the susceptibility of bituminous mixtures to moisture damage. Measured properties are impression depth measurements, number of passes at the stripping inflection point, and number of passes to failure.

2 Reference Documents:

2.1 *MT Manual:*
MT 303 Method of Sampling Bituminous Paving Mixtures
MT 314 Bulk Specific Gravity of Compacted Bituminous Mixtures
MT 321 Maximum Specific Gravity of Bituminous Mixtures
MT 332 Gyratory Compaction of Bituminous Mixtures
MT 335 Linear Kneading Compaction of Bituminous Mixtures
Manufacturer's Operation Manual for equipment used

3 Apparatus:

2.1 *Wheel-tracking Device* - An electrically powered device capable of moving a steel wheel with a diameter of 203.6 mm (8 in.) and width of 47 mm (1.85 in.) over a test specimen.

2.1.1 The load applied by the wheel is 705 N (158 lbs.). The wheel load is maintained ± 5% for the duration of the test excluding the cycles that are interrupted by stopping the process.

2.1.2 The wheel unidirectionally travels approximately 52 passes across the slab per minute.

2.2 Temperature Control System:

2.2.1 A water bath capable of controlling the temperature within ± 2.0°C over a range of ambient temperature to 70°C. This bath has a mechanical circulating system to stabilize the water temperature.

2.3 *Impression Measurement System* - A Linear Variable Differential Transducer (LVDT) device capable of measuring the depth of the impression of the wheel within 0.5 mm, over a minimum range of 20 mm. The system shall be mounted to measure the depth of the impression at several points in the path of the wheel and at the midpoint of the wheel's path on the slab. The impression is measured at intervals within 10 to 400 passes of the wheel without stopping the wheel.

2.4 *Wheel Pass Counter* - A device that counts each wheel pass over the slab. The signal from this counter is coupled to the wheel impression measurement, allowing for the depth to be correlated with the number of wheel passes.

2.5 *Sample Mounting System* - A tray is mounted to the machine so that movement of the sample is restricted to less than 0.5 mm during testing. The system supports the sample, allowing for free circulation in the water bath on all sides of the sample.

3 Sample:

3.1 *Field Samples* - Samples for testing should have a thickness that is more that three times the nominal maximum aggregate size.

3.1.1 Slabs -The formula for the volume of a slab is as follows: length x width x thickness. The amount of material to batch for each slab with 6% air voids is determined by multiplying the sample length x width x thickness in cubic centimeters by the sample's maximum specific gravity (Gmm) x 0.94.

Mass for sample = 5283 cm^3 x 1 gm/cm^3 x Gmm x 0.94

Compact and prepare plant mix into slabs using MT 335 Linear Kneading Compaction of Bituminous Mixtures.

3.2 *Field Compacted Gyratory Samples* - Two gyratory samples produced to the same requirements are paired and tested or a sample of 115 mm may be cut to yield two samples that are 55 mm in height. The gyratory specimens are fabricated with air voids in the range of N design. The design target air voids (VTM) for all current bituminous mixtures is 3.4% - 4.0%. Each sample is cut to fit the form. The height is adjusted and each sample is cut on a chord that is at least 35 mm longer than the width of the test wheel and parallel to the vertical axis of the specimen. The two samples are mounted so that the chords are together and the wheel rolls on the uncut faces of the specimens. The wheel path follows the diameter of each half of the sample through the center of the chords. A tolerance of $\pm$ 5 mm offset from the center is allowed.

3.2.1 *Gyratory Specimens* - The height of a compacted gyratory specimen is 115 mm $\pm$ 3 mm and the diameter is 150 mm. Compact each specimen to N design with the number of gyrations shown on the mix design. Field compacted samples produced to specification parameters are used. Using a diamond saw cut two specimens the same height.

3.3 *Ten Inch Cores* - Cut field cores with a bit with a nominal 10-inch diameter. Complete the preparation of the cores for testing by removing the bottom lift/s of plant mix to achieve a height of two and one-half inches to four inches. Separate the plant mix lifts by chilling the core and splitting the sample on the lift line with a metal wedge. The wedge is successively placed at points on the lift line around the circumference of the specimen and tapped with a hammer. The core will cleanly cleave on the lift line. An alternative is to cut the core with a diamond saw at the desired point, taking care to orient the cut perpendicular to the axis of the vertical core.

3.4 *Laboratory Produced Mix* - Before mixing bituminous mixtures for testing, all of the pans and implements should be "buttered". Heat materials to be mixed in a laboratory to the mixing temperature range in a forced draft or convection oven. Do not overheat the samples.

4 Procedure:

4.1 Position the frame holding the sample into the wheel-tracker so that the loading arm of the wheel is approximately horizontal when it rests on the slab. Insure that the setting of the machine is the same as those required for the specification. These are wheel force, temperature of environment, stroke length, speed and any other variables described in the procedure. Enter the number of test passes required by the specification.

4.2 Lower the wheel onto the slab and fill the wheel-tracker with water. When the water has been at test temperature (50°C unless otherwise specified) for 30 minutes, make ten passes with the loaded wheel. This establishes zero. Record the amount of impression of the specimen at intervals of 10 to 400 cycles until the test sequence is complete. If the impression exceeds the preset limit, the test will conclude and the cycles to failure will be reported. If the specimen cycles the number of times required by the contract and does not reach the impression depth defined as failure, record the impression depth at the conclusion of the testing.

5 Report:

5.1 The report for the results of testing samples using the wheel tracker must contain the following information:

5.1.1 Cover Sheet: Date Sampled, Project Number, Project Name, Binder Content (how %AC was obtained), Binder Grade, Sample Type

5.1.2 Configuration Settings: Conditioning Time, Maximum Number of Passes, Wheel Travel, Force Setting, Water Temperature, Average Final Impression, Sample Frequency, Graph (number of passes on the x-axis and impression depth on the y-axis).

5.2 Report the Average Final Impression determined by the software as the Hamburg test result. If multiple tests are run, report the average as the Hamburg test result.

5.3 Verify that the water bath temperature is within 1.0°C of the temperature readout.

5.4 Verify that the LVDT height is within 0.1 mm at each height tested with each of three calibration blocks that span the range of the test or use an LVDT calibration program and apparatus.

5.5 Verify the accuracy of the force application to the specimens within 2 kilograms.

METHODS OF SAMPLING AND TESTING
MT 335-04
LINEAR KNEADING COMPACTION OF BITUMINOUS MIXTURES

1 Scope:

1.1 Use this test method for preparing compacted slabs of bituminous mixture for testing on Wheel-Track Devices.

2 Reference Documents:

2.1 ***MT Manual:***

MT 303	Method of Sampling Bituminous Paving Mixtures
MT-309	Reducing Samples of Hot Mix Asphalt to Testing Size
MT 314	Bulk Specific Gravity of Compacted Bituminous Mixtures
MT 321	Maximum Specific Gravity of Bituminous Mixtures
MT 332	Gyratory Compaction of Bituminous Mixtures
MT 334	Hamburg Wheel-Track Testing of Compacted Bituminous Mixtures

3 Apparatus:

3.1 *Linear Kneading Compactor* - A slab of plant mix is compacted by applying pressure to the plant mix through a series of rectangular parallel plates. The sample is placed in an open top steel box with the desired dimensions. Closely fitting steel plates are placed in a vertical row across the plant mix. A steel roller travels back and forth on the row of plates and successively applies pressure to the plant mix through the plates. This compacting motion continues until the height of the sample of plant mix is reduced to the height calculated to yield the desired voids.

3.1.1 *Steel Wear Plate* - 10.125" wide, 12.6" long, .125" high

3.1.2 *Steel Compacting Plates* - 3.6" high

3.1.3 *Steel Compaction Carrier Box* - 10.25" wide, 12.625" long, 6" high

3.2 *Temperature Control System* - An oven which can maintain temperatures (250°F to 350°F).

3.3 Rubber Mallet

4 Sample:

4.1 Field Samples - The top lift or lifts of plant mix are tested. Samples for testing should have a thickness that is more that three times the nominal maximum aggregate size.

4.1.1 Slabs -The formula for the volume of a slab is as follows: length x width x thickness. The amount of material to batch for each slab with 6 ± 1% air voids is determined by multiplying the sample length x width x thickness in cubic centimeters by the sample's maximum specific gravity (Gmm) x 0.94.

Mass for sample = 5283 cm^3 x 1 gm/cm^3 x Gmm x 0.94

4.1.2 *Laboratory Produced Mix* - Before mixing bituminous mixtures for testing, all of the pans and implements should be "buttered. Heat materials to be mixed in a laboratory to the mixing temperature range in a forced draft or convection oven. Do not overheat the samples.

5 Procedure:

5.1 Make sure plant mix is up to compaction temperature, if not, place in the oven. Mix and quarter in accordance to MT-309 to approximate sample sizes.

5.2 Weigh out two each sample size slabs. Note that prepared lab samples are pre-made to sample size. Return second sample to the oven to maintain compaction temperature range.

5.3 Take preheated mold plate out of oven and place in compaction carrier box. Load sample into compaction carrier box and place the steel parallel plates vertically on top of the sample mixture. To level plates on the sample, use a rubber mallet if needed.

5.4 Close the Kneading Compactor door and press the power on and start buttons. This will move the sample under the compaction wheel.

5.5 Apply pressure with the hydraulic jack to a load which will compact the sample material to voids of $6 \pm 1\%$. Maintain a constant pressure until sample reaches proper voids.

5.6 Press the stop button to draw the sample back to the original starting point. Remove steel plates and side walls. Remove slab along with the bottom plate and cool to room temperature (to the touch).

5.7 Repeat the procedure for the second sample.

5.8 Determine bulk density using MT 314 Bulk Specific Gravity of Compacted Bituminous Mixtures.

6 Report:

6.1 Report the Bulk Specific Gravity of Compacted Bituminous Mixtures and calculate the voids in the mixture using MT-321- Maximum Specific Gravity of Bituminous Mixtures (Rice Gravity).

7 Calibration / Equipment Verification:

7.1 The inside form dimensions of the steel compaction carrier box is critical for this procedure.

BACK

CURRENT DATE OF REVISION
MT-400 SECTION (MISCELLANEOUS)

Test Method No.	Title	Pages	Date of Publication or Revision
MT-401	Sampling and Inspecting Corrugated Aluminum Pipe	pp 1-2	May 2004
MT-402	Sampling and Testing Corrugated Steel Pipe	pp 1-2	May 2004
MT-403	Sampling and Inspection of Seeding and Landscaping Materials	pp 1-3	May 2004
MT-404	Inspecting Wood Products	pp 1	May 2004
MT-405	Wire Cloth Sieves for Testing Purposes	pp 1-6	May 2004
MT-406	Sampling and Inspection of Signing Material and Signs	pp 1-5	May 2004
MT-407	Vacant		
MT-408	Vacant		
MT-409	Vacant		
MT-410	Inspection, Sampling, Testing and Acceptance of Paint	pp 1-3	May 2004
MT-411	Vacant		
MT-412	Topsoil Sampling, Sample Preparation and Testing	pp 1-2	May 2004
MT-413	Inspection of Fencing Materials	pp 1-3	May 2004
MT-414	Method of Acceptance for Reinforcing Steel	pp 1-5	May 2004
MT-415	Vacant		
MT-416	Random Sampling Technique	pp 1-8	May 2004
MT-417	Procedure for Reducing Field Samples to Testing Size	pp 1-3	May 2004
MT-418	Method of Acceptance for Miscellaneous Welded Items	pp 1	May 2004
MT-419	Method of Sampling and Sieve Analysis of Glass Beads	pp 1	May 2004
MT-420	Procedure to Check for Leaks Under Hydrostatic Pressure	pp 1-3	May 2004
MT-421	Sampling Construction Fabrics	pp 1-2	May 2004
MT-422	Method of Test for Surface Smoothness and Profile	pp 1-11	May 2004

METHODS OF SAMPLING AND TESTING
MT 401-04
METHOD OF SAMPLING AND INSPECTING CORRUGATED ALUMINUM PIPE
(AASHTO M196, M197)

1 Scope:

1.1 This specification covers the testing and inspection guidelines for aluminum clad alloy culverts and underdrains.

2 Referenced Documents:

2.1 ***AASHTO:***
M196 Corrugated Aluminum Pipe for Sewers and Drains
M 197 Aluminum Alloy Sheet for Corrugated Aluminum Pipe

ASTM:
B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate

3 Sampling:

3.1 Sampling shall be performed or witnessed by the testing agency at the point of fabrication.

3.2 Random sampling shall consist of at least one set of three 1" x 12" samples per gauge, alloy and temper, lot number and type of corrugation. Samples shall be obtained a minimum of 3" from any edge.

3.3 Previously tested material that is properly marked and accepted need not be re-sampled but must be listed in the test report.

3.4 In the event that the samples fail to comply, two additional sets of three samples will be taken from the same gauge, alloy and temper, lot number and type of corrugation. Both sets must comply with the requirements or the entire lot number will be rejected.

3.5 Each corrugated sheet used in annular corrugated pipe, and each 2 ft. (0.6m) to 5 ft. (1.5m) of coiled sheet used in helically corrugated pipe, shall be identified by the fabricator showing the following:

3.5.1 Name of sheet manufacturer.

3.5.2 Identification of the pipe fabricator, if different than the sheet manufacturer.

3.5.3 Alloy and temper.

3.5.4 Specified thickness.

3.5.5 Fabricator's date of corrugating or forming into pipe by a six (6) digit number indicating in order the year, month and day of the month.

3.6 The marking shall be applied to the sheet by a permanent method such as coining into the metal. This identification shall appear on the outside of the pipe.

3.7 *Sheet Manufacturer's Analysis:*
The manufacturer of each brand shall furnish a certificate setting forth the name or brand of aluminum alloy to be furnished, and a statement that the material conforms to the specified chemical composition limits. The certificate shall be sworn to for the manufacturer by a person having legal authority to bind the company.

3 Fabrication: (continued)

3.8 *Sheet Manufacturer's Guarantee:*
The manufacturer of the sheets shall submit, with the analysis, a guarantee providing that all aluminum alloy furnished shall conform to the applicable requirements of the latest revision of ASTM B209 for Alclad alloy 3004-H34 unless otherwise specified and shall bear a suitable identification brand or mark, and shall be replaced without cost to the purchaser when not in conformity with the specified analysis, sheet thickness, or cladding thickness, and the guarantee shall be so worded as to remain in effect so long as the manufacturer continues to furnish material.

3.9 Fabrication of the corrugated aluminum pipe shall conform to the requirements of AASHTO M 196, the Standard Specifications, and the plans for the specific project, and the Special Provisions.

4 Certification:

4.1 The testing agency shall submit appropriate manufacturer's mill test reports and chemical analysis representing each lot number used. The certification shall be submitted with the samples, and under separate cover. The reports shall include the following:

4.1.1 Lot number.

4.1.2 Gauge.

4.1.3 Corrugation size.

4.1.4 Diameter and quantity of pipe.

4.1.5 Type of seam.

4.1.6 Name of supplier.

4.1.7 Montana highway project for which the material is designated.

4.1.8 Two copies of Form 407 will accompany the material to the project site.

5 Approval for Shipments of Culverts

5.1 Culverts and/or related material shall not be approved for shipment until they have been found to comply with our specifications.

5.2 Evidence of approval shall be by means of the inspecting agency's ID stamp or tag placed on a noticeable location on each section of the inspected material.

5.3 In the event of any questions pertaining to the approval for shipment of culverts and/or related material, contact the Materials Bureau.

6 Field Inspection and Acceptance

6.1 The field inspection shall be made by the Project Manager who shall be furnished by the seller with an itemized statement of the sizes and lengths of culvert pipe in each shipment. This inspection shall include an examination of the culvert pipe for deficiency in length of finished pipe, and any evidence of damage during shipment. Along with the proper approval stamp or tag from the inspecting agency.

METHODS OF SAMPLING AND TESTING
MT 402-04
METHOD OF SAMPLING AND TESTING CORRUGATED STEEL PIPE (AASHTO M 36)

1 Scope:

1.1 The specification covers corrugated steel pipe intended for use for storm water drainage, under-drains, the construction of culverts, and similar uses. The steel sheet used in fabrication of the pipe has a protective metallic coating of zinc (galvanizing), aluminum, or aluminum-zinc alloy.

2 Referenced Documents:

2.1 ***AASHTO:***
M 36 Corrugated Steel Pipe, Metallic-Coated, for Sewers and Drains

3 Sampling Procedure:

3.1 Sampling shall be performed or witnessed by MDT or an approved inspecting agency at the point of manufacture.

3.2 Random sampling shall consist of at least one set of three 3" x 3" samples per gauge, heat number, lot number and type of corrugation. Samples shall be obtained a minimum of 3" from any edge.

3.3 Previously tested material that is properly marked and accepted need not be re-sampled, but must be listed in the test report.

3.4 In the event that the samples fail to comply, two additional sets of three samples will be taken from the same gauge, heat number, lot number and type of corrugation. Both additional sets must comply with the requirements or the entire lot number will be rejected.

4 Fabrication:

4.1 Fabrication of the corrugated steel pipe shall conform to the requirements of AASHTO M 36, the Special Provisions, the Standard Specifications, and the plans for the specific project.

5 Certification:

5.1 The inspecting agency shall verify that all materials are in compliance with the "Buy America" provision in the Montana Standard Specifications for Road and Bridge Construction. Upon receipt of the materials, the Contractor will submit the appropriate test reports and chemical analysis representing each lot number on the Contractors Certificate of Compliance, Form 406. The reports shall include the following:

5.1.1 Lot number

5.1.2 Heat number.

5.1.3 Gauge.

5.1.4 Corrugation size.

5.1.5 Diameter and quantity of pipe.

5 Certification: (continued)

5.1.6 Type of seam.

5.1.7 Weight of coating in oz/ft² or g/m².

5.1.8 Name of supplier.

5.1.9 Montana Department of Transportation project for which the material is designated.

5.1.10 Two copies of the report are to be forwarded to the District Laboratory.

6 Approval for Shipment of Culverts:

6.1 Culverts and/or related material shall not be approved for shipment until they have been found to comply with our specifications.

6.2 Evidence of approval shall be by means of the inspecting agencies ID stamp or tag placed on a noticeable location on each section of the inspected material.

6.3 In the event of any questions pertaining to the approval for the shipment of culverts and/or related material, contact the Materials Bureau.

7 Field Inspection and Acceptance:

7.1 Field inspection shall be made by the Engineering Project Manager who shall be furnished by the seller with an itemized statement of the sizes and lengths of culvert pipe in each shipment. This inspection shall include an examination of the culvert pipe for deficiency in length and any evidence of damage during shipment along with the proper approval stamp or tag from the inspecting agency and be submitted on a Form 46.

METHODS OF SAMPLING AND TESTING
MT 403-04
SAMPLING AND INSPECTION OF SEED, FERTILIZER MULCH, EMULSIFIED BINDER, PEAT MOSS AND NURSERY STOCK

1 Scope:

1.1 Sampling, sample preparation and submittal, supervision of seed blending.

2 Referenced Documents:

2.1 ***MT Manual:***
MT 412 Topsoil Sampling, Sample Preparation and Testing

3 Sampling Procedure:

3.1 All proposed seed, other than Montana certified "blue tag" seed, will be sampled under MDT supervision. Resampling will not be required if the proposed seed has been pretested at the grain and seed laboratory at Montana State University within a period of twelve (12) months. A miscellaneous sample sheet listing the supplier's name and all the information given on the purity and germination tag must be submitted to the Materials Bureau. List the name and approximate number of each kind or specie of restricted noxious weed seeds occurring per pound on the purity and germination tag. Acceptance of seed is based on compliance with the Standard Specifications for Road and Bridge Construction.

3.2 When sampling seeds in bags, a trier long enough to reach all areas in the bag will be used. The trier must be designed so that it will remove an equal volume of seed from each part of the bag through which the trier travels. Unless the trier has partitions in the seed chamber, it must be inserted into the bags horizontally. Sample non-free-flowing seeds difficult to sample with a trier by thrusting the hand into the seed and removing representative portions. When a sample is taken with the hand, insert the hand flat and with the fingers together. Keep the fingers together as the hand is closed and withdrawn. Because of possible segregation, hand samples should be taken from various locations in the bags.

3.2.1 Seed in bags.

3.2.1.1 For lots of one to six bags, sample each bag.

3.2.1.2 For lots of more than six bags, sample five bags plus at least 10% of the number of bags in the lot. Round numbers with decimals to the nearest whole number. Regardless of the lot size, it is not necessary to sample more than 30 bags.

3.2.1.3 Closed and open bags should be sampled with a long trier, probe, or bag sampler extending the full length of the bag. In sampling open bags it must be recognized that the sample may not represent the original shipment.

3.2.1.4 A trier or probe is available from the Materials Bureau on request and must be returned immediately upon completion of sampling.

3.2.1.5 Seed which has been pretested under Materials Bureau supervision need not be resampled by project personnel. If there is a reason to believe that the material received on the project has not been pre-tested, the sampling procedure described above shall be adhered to.

3 **Sampling Procedure:** (continued)

3.3 Submit a one quart (one liter) container for each lot of seed sampled. Should the total quantity of seed sampled be in excess of one quart (one liter), reduce the sample by means of quartering or splitting.

3.4 Submit the seed sample along with the purity and germination tag directly to the Seed Lab at Montana State University. Submit a miscellaneous sample sheet with the following information to the Materials Bureau: all pertinent project information, supplier's name and address, kind of seed, all of the information given on the purity and germination tag and the amount of seed the sample represents.

3.5 Blending supervision - Seed blending performed in the field will be supervised on the job site by project personnel. Arrangements will be made for the supervision of blending when performed by a dealer or supplier. A blending report will be submitted to the Materials Bureau.

3.6 On each seeding project, retain a one quart container of each blend until such time as the project has been completed and accepted. The same will apply to seed not incorporated in a blend, but applied directly. This will constitute a referee sample should a question arise relative to the purity and germination of the original sample.

4 **Fertilizer:**

4.1 Sampling will be performed by field personnel at the project site. In the case of blended fertilizer, a sample of the blended material will be sampled for analysis. Obtain sufficient material to fill a one quart (one liter) container from the top, center, and bottom of each fertilizer container to be sampled. Only one sample will be required from each lot, except that sampling is not required for projects under 500 pounds.

4.2 Each sample submitted to the Materials Bureau will be accompanied by the certified chemical analysis tag, a miscellaneous field sheet listing the supplier's name, the kind of fertilizer, the lot number, all of the information given on the certified chemical analysis tag, and the total pounds the sample represents.

5 **Mulch:**

5.1 *Vegetative mulch* - The project inspection of mulch for conformance with the Standard Specifications will be arranged by field personnel. In connection with this inspection, the Materials Bureau will be furnished with a report which will include the following information: Source, type, condition, purity, and moisture content of the mulch.

5.2 *Wood cellulose fiber mulch* - The project inspection of mulch for conformance with the Standard Specifications will be arranged by field personnel. In connection with this inspection, the Materials Bureau will be furnished with a report, which will include the following information: Source, type, and moisture content of the mulch.

5.3 *Peat moss* - A one pound representative sample will be submitted to the Materials Bureau for pH analysis.

5.4 *Bark chip mulch* - Bark chips derived from the bark of Douglas Fir, Pine, or Hemlock will be acceptable. All material must be reasonably free from weed seeds and other foreign material such as grasses, chaff, and substances toxic to plant growth. Individual bark chips will have a maximum dimension of 3 inches and not more than 10% of the chips can pass through a 3/4 inch sieve. A 25-pound sample will be submitted to the Materials Bureau for testing.

5 Mulch: (continued)

5.5 *Manure* - The term "Manure" will apply to stockpiled, well-rotted cattle, sheep, or horse manure or combinations of such, more than one year old, reasonably free of debris and foreign matter. Before being used in any planting operation, the manure must be shredded to break up large chunks and to assure proper mixing with other materials. Before any manure is hauled to the project site it must be approved by the landscape architect or engineer.

5.6 *Fabricated netting* - The project inspection of netting for conformance with the Standard Specifications will be arranged by field personnel. In connection with this inspection, the Materials Bureau shall be furnished with a report which shall include the source, type, and condition of the material.

6 Emulsified Binder:

6.1 When the quantity of emulsified binder is in excess of 10,000 gallons, a one-quart representative sample of the emulsified asphalt proposed for use on the project shall be submitted to the Materials Bureau. Ship emulsified binder in plastic containers.

7 Topsoil:

7.1 With the exception of topsoil which has been stripped and is stockpiled for later replacement, a two pound sample of each kind or type will be sampled and tested in accordance with MT-412.

8 Sod:

8.1 The material will be inspected on-site, a miscellaneous field sample sheet (Form 46) will list source, grass specie, and thickness of sod, and also the total quantity of material represented by the sample, and forwarded to the Materials Bureau.

9 Nursery Stock:

9.1 The project inspection of nursery stock will be performed by the Manager, Field Project Unit for conformance with the specifications contained in the project proposal. In connection with this inspection, the Materials Bureau is to be furnished with a report which will include the following information: supplier, stock name, quantity, condition, minimum and maximum size or spread of trees and shrubs, whether of nursery or collected stock, whether stock is bare-root, balled and burlapped or plotted and number of trees and shrubs accepted.

9.2 The following is an example of a nursery stock inspection report:

COMMON NAME	BOTANICAL NAME	QUANTITY	SIZE
Ponderosa Pine	Pinus ponderosa	6	1'6" - 1'0"

All of the specified size, all potted nursery stock, all in good condition and all accepted.

Common Lilac	Syringa Vulgaris	140	25" - 35"

All of the specified size, all nursery stock, all in good condition and all accepted.

METHODS OF SAMPLING AND TESTING
MT 404-04
METHOD FOR INSPECTING WOOD PRODUCTS
(Montana Method)

1 Scope:

1.1 This method includes the inspection of all wood products at the mills, the treating plant and after shipment to the job-site.

1.2 A detailed procedure for inspecting wood products is not included in this method because the primary responsibility for such inspections is charged to the Inspector at the Materials Bureau. In the event division or other personnel are required to make inspections of wood products, attention is directed to paragraph 5.1, below.

2 Mill Inspection:

2.1 Plant inspection of all wood products will consist of checking grade, dimensions, etc., in accordance with the applicable section in the Standard Specifications.

3 Treating Plant Inspection:

3.1 (Wood products to be treated must be inspected in the white to determine its suitability for treatment.) After treating is completed, the wood products must be inspected again for:

3.1.1 Adequacy of the treatment.

3.1.2 Damage which may have been caused by or during the treating cycle, or in subsequent handling.

3.2 It is essential that the treating plants call the Materials Bureau at least 48 hours in advance of the time requested for an inspection.

4 Final Inspection:

4.1 At the time of final inspection, all acceptable large timbers (guardrail posts, pilings, sign posts, etc.) are individually stamped with the Circle (M) stamping hammer which denotes acceptance prior to shipment.

4.2 The acceptance of small items (fence posts, etc.) prior to shipment is indicated by inspection seals attached to each bundle.

5 Job-Site Inspection:

5.1 In the event that the inspector from the Materials Bureau is unable to perform the inspection at the plant, Division personnel may be called upon to perform the inspection in the field. Division personnel are directed to contact the Materials Bureau for specific instructions.

5.2 All wood products are subject to final field approval after delivery to the project.

METHODS OF SAMPLING AND TESTING
MT 405-04
WIRE CLOTH SIEVES FOR TESTING PURPOSES
(Modified AASHTO M 92)

1 Scope:

1.1 This specification covers the requirements for the design and construction of sieves using a medium of woven-wire cloth mounted in a frame for use in testing for the classification of materials according to designated nominal particle size and wire cloth, meeting the specifications of Table 1, to be designated test grade wire cloth. All subsequent references to wire cloth shall mean test grade wire cloth.

2 Referenced Documents:

2.1 *AASHTO:*
M 92 Wire Cloth and Sieves for Testing Purposes

3 Sieve Cloth Requirements:

3.1 Wire cloth used in U.S.A. standard testing sieves meeting the specifications shown in Table 1 shall be designated "test grade". Test grade cloth shall be woven from stainless steel, brass, bronze, or other suitable wire with a plain weave, except that cloth with openings of 63 µm (No. 230) and finer may be woven with a twill weave. The wire shall not be coated or plated.

3.2 The openings of the sieve cloth of successive sieves from a base of 1 mm in the ration of approximately $4\sqrt{2}$:1.

3.3 All measurements of openings and wire diameters shall be made along the midpoints of the opening.

3.4 Sieve cloth shall conform to the dimensional requirements of Table 1. The average opening (distance between parallel wires measured at the center of the opening), in the horizontal and vertical directions measured separately, shall conform to the values in Column 1, within the permissible variation in average opening size shown in column 4. Not more than 5% of the openings shall exceed the value shown in Column 5. The maximum individual opening size shall not exceed the value shown in Column 6.

3.4.1 The average diameter of the horizontal and vertical wires, measured separately, shall conform to the diameter in Column 7 within the tolerances in Footnote A of Table 1.

3.5 Wires shall be crimped in such a manner that they will be rigid when in use.

3.6 There shall be no punctures or obvious defects in the wire cloth.

4 Test Sieve Frames:

4.1 *General Requirements* - Frames for wire cloth sieves shall be constructed in such a manner as to be rigid. The wire cloth shall be mounted on the frame without distortion, looseness or waviness. To prevent the material being sieved from catching in the joint between the wire cloth and the frame, the joint shall be filled smoothly or constructed so the material will not be trapped.

4.2 *Standard Frames*--The standard sieve frame shall be circular with nominal diameters of 3, 6, 8, 10 or 12 inches (76, 512, 203, 254, or 305 mm) as may be specified. The dimensions shall conform to the requirements of Table 2. Frames shall be made from noncorrosive material such as brass or stainless steel and be of seamless construction.

4 **Test Sieve Frames:** (continued)

4.2.1 The bottom of the frame shall be constructed so as to provide an easy sliding fit with any sieve frame of the same nominal diameter conforming to the specified dimensions.

4.2.2 The joint or fillet at the connection of the sieve cloth to the frame will provide a minimum clear sieving surface with a diameter equal to the nominal diameter less 0.5 in. (13 mm).

4.3 *Nonstandard Frames* – Other sieve frames may be square, rectangular, or circular. The frame may have the sieve cloth permanently installed, or be designed to permit replacement. The provisions of 5.1 apply.

Note 1 – While there are no requirements for nesting of nonstandard frames, care should be applied in the use to prevent loss of material during analysis.

4.4 *Pans and Covers* – Pans and covers for use with sieves shall be made so as to nest with the sieves. Pans with extended rims ("stacking skirts") shall be furnished when specified. The pans and covers shall conform to the dimensions of Table 2.

5 **Product Marking:**

4.1 Each sieve shall bear a label marked with the following information:

4.1.1 U.S.A. Standard Testing Sieve,

4.1.2 ASTM designation E 11,

4.1.3 Standard sieve designation (from Table 1, Column 1),

4.1.4 Name of manufacturer or distributor, and

4.1.5 Alternative sieve designation (from Table 1, Column 2) Optional.

4.1.6 Each test sieve shall bear a unique serial number permanently engraved or etched onto the sieve frame, skirt or nameplate.

TABLE 1 Nominal Dimensions, Permissible Variations for Wire Cloth of Standard Test Sieves (U.S.A. Standard Series)

Sieve Designation Standard[b] mm	Alternative	Nominal Sieve Opening, in.[c]	Permissible Variation of Average Opening from the Standard Sieve Designation mm	Maximum Opening Size for Not More than 5% of Openings mm	Maximum Individual Opening mm	Nominal Wire Diameter, mm[a]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
125	5 in.	5	±3.7	130.0	130.9	8.0
106	4.24 in.	4.24	±3.2	110.2	111.1	6.40
100[d]	4 in.[d]	4	±3.0	104.0	104.8	6.30
90	3½ in.	3.5	±2.7	93.6	94.4	6.08
75	3 in.	3	±2.2	78.1	78.7	5.80
63	2½ in.	2.5	±1.9	65.6	66.2	5.50
53	2.12 in.	2.12	±1.6	55.2	55.7	5.15
50[d]	2 in.[d]	2	±1.5	52.1	52.6	5.05
45	1¾ in.	1.75	±1.4	46.9	47.4	4.85
37.5	1½ in.	1.5	±1.1	39.1	39.5	4.59
31.5	1¼ in.	1.25	±1.0	32.9	33.2	4.23
26.5	1.06 in.	1.06	±0.8	27.7	28.0	3.90
25.0[d]	1 in.[d]	1	±0.8	26.1	26.4	3.80
22.4	7/8 in.	0.875	±0.7	23.4	23.7	3.50
19.0	3/4 in.	0.750	±0.6	19.9	20.1	3.30
16.0	5/8 in.	0.625	±0.5	16.7	17.0	3.00
13.2	0.530 in.	0.530	±0.41	13.83	14.05	2.75
12.5	1/2 in.[d]	0.500	±0.39	13.10	13.31	2.67
11.2	7/16 in.	0.438	±0.35	11.75	11.94	2.45
9.5	3/8 in.	0.375	±0.30	9.97	10.16	2.27
8.0	5/16 in.	0.312	±0.25	8.41	8.58	2.07
6.7	0.265 in.	0.265	±0.21	7.05	7.20	1.87
6.3[d]	1/4 in.[a]	0.250	±0.20	6.64	6.78	1.82
5.6	No. 3½	0.223	±0.18	5.90	6.04	1.68
4.75	No. 4	0.187	±0.15	5.02	5.14	1.54
4.00	No. 5	0.157	±0.13	4.23	4.35	1.37
3.35	No. 6	0.132	±0.11	3.55	3.66	1.23
2.80	No. 7	0.111	±0.095	2.975	3.070	1.10
2.36	No. 8	0.0937	±0.080	2.515	2.600	1.00
2.00	No. 10	0.0787	±0.070	2.135	2.215	0.900
1.70	No. 12[c]	0.0661	±0.060	1.820	1.890	0.810
1.40	No. 14	0.0555	±0.050	1.505	1.565	0.725
1.18	No. 16	0.0469	±0.045	1.270	1.330	0.650
1.00	No. 18	0.0394	±0.040	1.080	1.135	0.580
0.850	No. 20	0.0331	±0.035	0.925	0.970	0.510
0.710	No. 25	0.0278	±0.030	0.775	0.815	0.450
0.600	No. 30	0.0234	±0.025	0.660	0.695	0.390
0.500	No. 35	0.0197	±0.020	0.550	0.585	0.340
0.425	No. 40	0.0165	±0.019	0.471	0.502	0.290
0.355	No. 45	0.0139	±0.016	0.396	0.425	0.247
0.300	No. 50	0.0117	±0.014	0.337	0.363	0.215
0.250	No. 60	0.0098	±0.012	0.283	0.306	0.180
0.212	No. 70	0.0083	±0.010	0.242	0.263	0.152
0.180	No. 80	0.0070	±0.009	0.207	0.227	0.131
0.150	No. 100	0.0059	±0.008	0.174	0.192	0.110

TABLE 1 Nominal Dimensions, Permissible Variations for Wire Cloth of Standard Test Sieves (U.S.A. Standard Series)

Sieve Designation		Nominal Sieve Opening, in.[c]	Permissible Variation of Average Opening from the Standard Sieve Designation	Maximum Opening Size for Not More than 5% of Openings	Maximum Individual Opening	Nominal Wire Diameter,
Standard[b] mm	Alternative		mm	mm	mm	mm[a]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0.125	No. 120	0.0049	±0.007	0.147	0.163	0.091
0.106	No. 140	0.0041	±0.006	0.126	0.141	0.076
0.0090	No. 170	0.0035	±0.005	0.108	0.122	0.064
0.075	No. 200	0.0029	±0.005	0.091	0.103	0.053
0.063	No. 230	0.0025	±0.004	0.077	0.089	0.044
0.053	No. 270	0.0021	±0.004	0.066	0.076	0.037
0.045	No. 325	0.0017	±0.003	0.057	0.066	0.030
0.038	No. 400	0.0015	±0.003	0.048	0.057	0.025
0.032[d]	No. 450[d]	0.0012	±0.003	0.042	0.050	0.028
0.025[d]	No. 500[d]	0.0010	±0.003	0.034	0.041	0.025
0.020[d]	No. 635[d]	0.0008	±0.003	0.029	0.035	0.020

TABLE 2 Dimensions of Standard Frames

Nominal Diameter	Mean Diameter, in. (mm)		Typical Frame[A]
In.	Inside at Top[B]	Outside of Skirt	Nominal Height[C] in. (mm)
3	3.000 + 0.030/-0.000 (76 + 0.76/ -0.00)	3.000 + 0.000/-0.030 (76 + 0.00/ -0.76)	1 1/4 (32) FH[D] 5/8 (16) HH
6	6.000 + 0.030/-0.000 (152 + 0.76/ -0.00)	6.000 + 0.000/-0.030 (152 + 0.00/ -0.76)	1 3/4 (45) FH 1 (25) HH
8	8.000 + 0.030/-0.000 (203 + 0.76/ -0.00)	8.000 + 0.000/-0.030 (203 + 0.76/ -0.76)	2 (50) FH 1 (25) HH
10	10.000 + 0.030/-0.000 (254 + 0.76/ -0.00)	10.000 + 0.000/-0.030 (254 + 0.00/ -0.76)	3 (76) FH 1 1/2 (38) HH
12	12.000 + 0.030/-0.000 (305 + 0.76/ -0.00)	12.000 + 0.000/-0.030 (305 + 0.00/ -0.76)	3 1/4 (83) FH 2 (50) IH 1 5/8 (41) HH

[A] Other frame heights are not precluded.
[B] Measured 0.2 in. (5 mm) below the top of the frame.
[C] Distance from the top of the frame to the sieve cloth surface.
[D] FH = full height, HH = half height, IH = intermediate height.

METHODS OF SAMPLING AND TESTING
MT 406-04
METHOD OF INSPECTING, SAMPLING, AND TESTING SIGNING MATERIAL, INSPECTION OF SIGNS, AND SUBMITTAL OF TEST AND INSPECTION REPORTS
(Montana Method)

1 Scope:

1.1 Following the determination of a successful bidder, and upon the letting of a project to contract, a letter is sent to the prime contractor by the Materials Bureau requesting the source of bid items in the contract. These items include signing material and signs. Upon receipt of the information, the Certification Inspection Supervisor in the Materials Bureau will arrange for inspection. The following procedures and requirements shall be observed whenever signs are included in a project.

2 Referenced Documents:

2.1 Montana Department of Transportation Detailed Drawings

3 Reporting:

3.1 A copy of all correspondence, test results, certificates and other pertinent documents shall be submitted to the Materials Bureau, attention Certification Inspection Supervisor.

4 Signing Material:

4.1 Inspection of signing material will be performed by either another state, by a commercial inspection and testing agency, or if the material was not pre-inspected by field personnel.

5 Sign Fabrication Inspection:

5.1 Sign fabrication inspection involves visual observation of sign materials, fabrication procedures, and the manufactured product to ensure that it will serve the intended purpose for its expected performance life.

5.2 Material specifications are outlined in the Standard Specifications for Road and Bridge Construction and in the contract special provisions. Materials used in the fabrication of highways signs are inspected by an inspection agency for each construction contract.

5.3 In-Plant sign inspection and approval does not constitute mandatory acceptance by the Project Manager of the delivered product. It is possible that signs may be damaged in transit because of inadequate packaging or poor handling and will be rejected at the project site. Approval of a sign at the point of fabrication means that the inspector has assured himself that all materials used meet the plan specifications and that finished signs are satisfactory in appearance and workmanship.

6 Materials:

6.1 *Inspection & Sampling:* Following is a listing of the materials used in the fabrication of signs and the required sampling procedures before the subject material may be approved for use.

6.2 6061 T6 or 5052 H38 Aluminum Sheeting can be accepted on certification of conformance and certified mill test reports. No sample is required unless deemed necessary by the Inspector. If samples are required, they shall be sampled as follows: Two samples of size 3/4 inch x 9 inch of

6 Materials: (continued)

each gauge will be taken from each consignment of aluminum received for signing. Samples will be oriented with the longer dimension parallel to the direction of rolling. The Materials Bureau will machine these samples to comply with ASTM E8-80A. A Certificate of Compliance including Certified Mill Test Reports of each gauge is required.

6.3 *Aluminum Sign Blanks:* Each consignment of aluminum sign blanks is spot checked with a micrometer for gauge thickness conformance. Certificates of Compliance and a Certified Mill Test Report of each gauge are required.

6.4 *6063 T6 Extruded Aluminum T-Sections (Wind Beam):* Certificates of Compliance, Certified Mill Test Reports, and Chemical Analysis are required for each order. No sample is required unless deemed necessary by the Inspector.

6.5 *HD (High Density) Plywood:* The minimum allowable plywood grade shall be B-B high density overlay 60/60 with amber overlay on both sides, and a minimum thickness of 3/4" or as shown on plans. A spot check on thickness requirements, grade-trademark for Grade and Type of plywood, and a letter attesting to the standard of the plywood received is required. No sample is required unless deemed necessary by the Inspector.

6.6 *Reflective Sheeting:* A portion of each roll will be visually inspected for imperfections. A Certificate of Compliance including the type, grade, color, and purchase order number is required for each roll used in the signing fabrication.

Note 1 -Reflective sheeting from each manufacturer will be sent to the Materials Bureau for reflectivity testing on an annual basis.

6.7 *Sign Faces:* No sampling is required for reflective or non-reflective sign faces. A visual inspection for conformance and imperfections will be performed on each order of sign faces received. A Certificate of Compliance is required for each shipment. The certificate will include type of material and purchase order number.

6.8 *Applied or Demountable Copy* A Certificate of Compliance is required for each order prior to usage. The reflective sheeting for <u>all</u> sign copies shall be Silver-White No. 2 (Parkway - if a 3M product). Encapsulated lens, wide angle reflective sheeting may be used when specified in the plans.

7 **Fabrication:** Items to be observed by the Inspector During Sign Fabrication:

7.1 Approved materials.

7.2 Visual check of material color and color match with a 150 watt flood light held at eye level at a distance of 50 feet from material being observed.

7.3 Visual check of uniform legend color tone and uniform reflectivity with a 150 watt flood light held at eye level at a distance of 50 feet from legend being observed.

7.4 Visual check of splices.

7.5 Fabrication

7.5.1 Correct thickness of aluminum or plywood.

7.5.2 Correct material for reflectorized and non-reflectorized signs, (sheeting and copy).

7 **Fabrication:** Items to be observed by the Inspector During Sign Fabrication: (continued)

7.5.3 Correct "T" sections (wind beam) and proper spacing of "T" sections, (Standard Drawing No. 619-04 and 619-06).

7.5.4 Correct spacing of rivets with heads painted to match signs, (Standard Drawing No. 619-04).

7.5.5 Correct spacing of aluminum clips on "T" sections on plywood, (Standard Drawing No. 619-06).

7.5.6 Correct sign size, color, and whether copy and background sheeting are reflectorized or non-reflectorized.

7.5.7 Corners of control signs rounded.

7.5.8 Corners of guide signs rounded when so noted on plans.

7.6 **Non-Standard Items:**

7.6.1 Conformance to contract special provisions. Conformance to special mounting details shown on the plans.

8 **Application of Materials:**

8.1 Use of approved equipment and qualified personnel.

8.2 Sheeting properly applied.

8.3 Absence of foreign particles under applied sheeting.

8.4 Absence of air bubbles under applied sheeting.

8.5 Absence of loose edges.

9 **Workmanship:**

9.1 Correct sign layout and size.

9.2 Sharp clear screened sign messages.

9.3 Proper horizontal and vertical spacing.

9.4 Correctly spelled words.

9.5 Symbols correctly depicted.

9.6 Back of sign clean and free of corrosion.

9.7 Sign number on back of guide signs.

10 **Design Conformance:**

10.1 Completed Signs:

10.1.1 All completed signs will conform to the Manual on Uniform Traffic Control Devices, and Standard Highway Signs as specified in the MUTCD, 1978 with addendums; except as may be provided for in the Montana Standard Drawings, Montana Sign Index, or contract plans and approved shop drawings.

10 Design Conformance: (continued)

10.1.2 All completed signs that are in conformance will be stamped on the back of the sign, by the inspector, with the inspecting agency's stamp of approval.

10.1.3 Test reports for signing material, inspected and sampled by a commercial agency, will be sent to the inspecting agency by the Materials Bureau upon completion of the tests.

10.1.4 Test reports for material sampled by field personnel will be issued upon completion of the tests.

10.1.5 The supplier for all major signing material must provide the manufacturer's Certificates of Compliance. Copies of all certificates will be kept in the Materials Bureau project files.

10.1.6 Acceptance reports for material used on pre-inspected signs that were supplied from out-of-state will be submitted to the field in the final report.

10.1.7 The field shall provide the Materials Bureau with inspection and acceptance reports whenever un-inspected signing material that has been supplied from out-of-state is delivered to the project. (Section 10.2.4).

10.2 Signs Supplied Locally or from Out-of-State:

10.2.1 Signs that have been supplied locally or out-of-state are inspected at the source as designated by the Materials Bureau. Following inspection, a report listing the number and kind of signs will be submitted to the field and to the Materials Bureau.

10.2.2 In the event that the signs have not been pre-inspected, the Materials Bureau shall require a Field Inspection and Acceptance Report in addition to the manufacturer's Certificates of Compliance (Section 10.1.5).

10.2.3 Signs are inspected for conformance with the Montana Department of Transportation specification requirements. Locally inspected signs will bear evidence of having been inspected by the presence of the inspecting agency's stamp of approval. Unpackaged signs will bear a stamp on the back of the sign, while packaged signs will bear a stamp on the package face.

10.2.4 Locally supplied signs that have not been inspected may be delivered to a project only in the case of extreme urgency for installation. For such cases, the suppliers have been directed to immediately forward a letter to the Materials Bureau and to the Project Manager describing the circumstances under which the signs (not inspected) were shipped. This letter must designate the project and location to which the signs were delivered and list the kind and quantity of signs. Signs that have been shipped without inspection shall not be accepted until the manufacturer has submitted this letter.

10.2.5 It is imperative that the Materials Bureau, attention Certification Inspection Supervisor, be informed of the field inspection and acceptance of all signs that do not show evidence of inspection at the source. The following information will be included in this inspection report:

10.2.5.1 Appearance and workmanship

10.2.5.2 Conformance to specifications

10.2.5.3 Type, size, and quantity

10.2.5.4 Gauge of aluminum

10.2.5.5 Thickness or ply of plywood

10.3 Final Signing Material and Sign Acceptance Reports:

10.3.1 Signing material and signs which have been inspected by a commercial agency will be accepted upon receipt of all required Certificates of Compliance.

10.3.2 Signing material and signs which have been supplied from out-of-state but which have not been inspected will be accepted upon receipt of required certificates from the supplier, a field inspection, and an acceptance report.

10.3.3 Signing material and signs which have been supplied from out-of-state and have been inspected by a commercial agency will be accepted on the reports issued by the agency.

10.3.4 Signing material and signs which have been supplied locally and have been inspected by the District will be accepted on the reports issued by the District.

10.3.5 All signing material and signs, regardless of source and inspection procedure, are subject to final field approval.

METHODS OF SAMPLING AND TESTING
MT 410-04
METHOD OF INSPECTION, SAMPLING, TESTING, AND ACCEPTANCE OF PAINT, EPOXY AND THERMOPLASTIC PAVEMENT MARKING MATERIAL
(Montana Method)

1 Scope:

1.1 This procedure describes the inspection, sampling, testing and acceptance of construction and maintenance traffic line paint, structural steel primers and finish coats delivered to construction and maintenance projects.

2 Reference Documents:

2.1 ***ASTM Standards, Federal Test Methods Std. 141:***

D-711 No - Pick-up Times for Traffic Paint

D-1640 Drying, Curing, or Film Formation of Organic Coatings at Room Temperature

D-969 Laboratory Determination of Degree of Bleeding of Traffic Paint

D-1210 Fineness of Dispersion of Pigment-Vehicle Systems

D-562 Consistency of Paints Using Stormer Viscometer

D-823 Producing Films of Uniform Thickness of Paint, Varnishes, and Related Products on Test Panels

D-522 Mandrel Bend Test of Attached Organic Coatings

D-1475 Density of Paint, Varnish, Lacquer and Related Products

D-4060 Abrasion Resistance on Organic Coatings by the Tabor Abaser

6192 Federal Test Method Std. No. 141 Method 6192

MT Manual:
MT-601 Montana Test Methods-Methods of Sampling and Testing

3 Sampling:

3.1 Two samples are required for each lot or batch of paint used on a project. Suitable containers for each type of paint are listed below.

3.1.1 Sample Waterborne paints using a clean, one-liter (quart), lined, metal can or plastic "Nalgene" bottle. **Do not use unlined metal containers for Waterborne paint samples.**

3.1.2 Sample Alkyd paints using a clean, one-liter (quart), unlined, metal "Asphalt" sampling can. **Do not use plastic "Nalgene" containers for Alkyd paint samples.**

3 Sampling: (continued)

3.1.3 Sample Epoxy paints using a clean, one-liter (quart), lined or unlined metal can or plastic "Nalgene" container.

3.1.4 Sample Aluminum Mastic paints using a clean, one-liter (quart), unlined metal "Asphalt" can. **Do not use plastic "Nalgene" containers for Aluminum Mastic paint samples.**

3.2 Construction Projects - Project quantities of 19 liters (5 gallons) or less: No field sample required. Attach the label from the paint container to a Miscellaneous Form 46 and submit to the Materials Bureau.

3.3 Construction Projects - Project quantities greater than 19 liters (5 gallons) but less than 95 liters (25 gallons): No field sample is required. Sample if the type or quality is suspect, at the option of the Department. Submit Manufacturer's Certification to the Materials Bureau attached to a Miscellaneous Form 45.

3.4 Construction Projects - Project quantities of 95 liters (25 gallons) or more:

3.4.1 Duplicate, one-liter (quart) samples will be taken from the thoroughly mixed contents of a striping machine or container representing each lot. Both samples will be forwarded to the Materials Bureau for testing with a Miscellaneous Form 45. Acceptance will be based on the test report issued by the Materials Bureau. **CONSTRUCTION PAINT WILL NOT BE PRETESTED AT THE POINT OF MANUFACTURE.**

4 Maintenance Traffic Paint:

4.1 Duplicate one-liter (quart) samples of thoroughly mixed paint per lot or batch will be sampled by the Montana Department of Transportation at the point of manufacture and be forwarded to the Materials Bureau for testing. Acceptance will be based on the test report issued by the Materials Bureau.

4.2 For each paint shipment received, a Field Inspection Report - Miscellaneous Material Form No. 46 shall be prepared and mailed to the Materials Bureau. This report shall indicate the type, quantity, and condition of the paint together with source information (Manufacturer and Lot No., etc.). The label may be taken from the container and attached to the inspection report to transmit the source information.

5 Epoxy Pavement Marking Material:

5.1 Epoxy pigment and catalyst will be sampled separately and submitted in accordance with 3.1.3 and submit to the Materials Bureau for testing. Manufacturer's certification will be attached to a Miscellaneous Form 45 and submitted with the samples.

6 Thermoplastic Pavement Marking Material:

6.1 Thermoplastic will be sampled at the point of application. Approximately ½ kilo (1 pound) of the solid material will be submitted to the Materials Bureau for testing. The inspector will supply sample containers. Manufacturer's certification will be attached to a Miscellaneous Form 45 and submitted with the samples.

7 Testing:

7.1 Test methods used for testing paint shall conform to ASTM, Federal Test Methods Standard No. 141, latest revisions, or tests and methods described below:

7 **Testing:** (continued)

7.1.1 Flexibility - Apply the paint to produce a 0.0762 mm (0.003 inch) dry film on a 0.25 mm (0.10") tin panel. Air dry at twenty-five (25) degrees centigrade plus or minus 2 degrees (25 °C ± 2°C) or 77 degrees Fahrenheit plus or minus 4 degrees (77 °F ± 4 °F) for at least four (4) hours and then bend over 6.4 mm (1/4 inch) diameter mandrel. The film shall not crack when subjected to the above prescribed flexibility test.

7.1.2 Adhesion: Prepare the panel as for the flexibility test. Place the panel on a 3.2 mm (1/8 inch) thick rubber pad. Strike a sharp blow with a ball peen hammer to cause an indentation of 1.27 mm to 2.54 mm (0.05 to 0.10 inch). There shall be no cracking, chipping or peeling when subjected to the above-prescribed test.

7.1.3 Skinning: In a 250 ml. paint container (1/2 pint), fill 1/2 full with the paint. Examine after 24 hours for skinning. There shall be no skinning.

7.1.4 Settling: Fill a 100 ml. centrifuge tube with paint and revolve for 2 hrs. at a speed producing a centrifugal force of 1,112 Newton (250 pounds). A separation of not more than 12.7 mm (1/2 inch) of the pigment is acceptable. The pigment in the bottom of the tube should be soft and easily dispersed with a spatula.

7.1.5 Abrasion: ASTM D-4060 (Test Method for Epoxy Traffic Paint).

7.1.5.1 Abrasion: Federal Test Method Std. No. 141, Method 6192. Panels may be coated by dipping, spraying or by means of film applicator. Dry at 25 °C ± 2 °C (77 °F ± 4 °F) for 24 hours, cure at 49 °C (120 °F) for 72 hours, cool to room temperature and subject to Tabor Abrasion Test using CS-10 wheels, 1000 gram load per wheel and at least 500 revolutions. The dry film thickness should not be less than 0.003 inches prior to testing. The Department performs this test starting with a wet paint thickness of 0.254 mm ± 0.051 mm (0.010 ± 0.002 inch).

7.1.6 Hiding: Use a Standard Horest Hiding Power Chart. Apply at a rate of 16.26 square meters (175 square feet) per 3.785 liters (one gallon). Visual examination will determine acceptance.

7.1.7 Film Appearance: Visual examination of dry film on tin panel is performed. The paint shall dry to a flat finish.

7.1.8 Light Resistance: Apply a wet film of 0.381 mm (0.012 inches) to two clean 76.2 mm x 127 mm (3x5 inches) tin panels and allow to dry horizontally for twenty-four (24) hours. Expose one (1) of the panels to direct sunlight or to a carbon arc light (no water spray) for a period equivalent to seven (7) hours of direct sunlight. The other panel shall not be exposed. Finally examine both panels and compare for darkening. The yellow paint shall not darken appreciably when subjected to the above-prescribed test.

METHODS OF SAMPLING AND TESTING
MT 412-04
TOPSOIL SAMPLING, SAMPLE PREPARATION AND TESTING

1 Scope:

1.1 It is intended that the procedure for sampling and testing topsoil shall apply (1) only to topsoil that has been imported from another source (other than the project), and (2) to any topsoil intended for use in planting lawns, shrubs, trees or other particular plants which require special soil. It is not necessary to sample or test topsoil (termed salvaging and placing) which has been stripped and is stockpiled for later replacement on median areas, outer separation areas and side slopes of roadway areas.

2 Referenced Documents:

2.1 ***AASHTO:***
T 2 Sampling of Aggregates

3 Sampling Procedures:

3.1 Samples shall be obtained from each kind or type of soil (homogeneous area) Soil types may be identified from visual appearance, present vegetative growth, or soils classification primary group from an Engineering Soil Survey.

3.1.1 Samples of sub-soils may also be taken from borings in conjunction with Engineering Soil Survey.

2.1.2 Samples from stockpiles or from loaded transports may be taken in accordance with procedures outlined in AASHTO T 2.

3.2 Samples from the layer of soil proposed for use as topsoil shall be labled "topsoil". Samples from the layer of soil over which the topsoil is to be placed shall be labeled "subsoil." Insignificantly small, unusual areas may be omitted in sampling.

3.3 A sample shall be a composite of material taken from three sample sites in the following manner:

3.3.1 Dig a V-shaped hole through the thickness of the layer of soil being sampled (if a surface sample) and remove a ½ inch thick slice of soil from one side of it.

3.3.2 Trim off from each side of the slice all but a thin ribbon of soil down the center of the spade face and place this in a clean bucket.

3.3.3 Mix equal size samples representing similar soils thoroughly and keep two pounds for testing.

3.4 The sampler shall identify the samples by number and the location from which they were taken. Observations concerning the soil's apparent ability to support plant growth such as the presence or absence of usual or unusual vegetative types, swamps, rock, salt encrustations, etc., should be noted and recorded with the identification data.

4 Sample Preparation:

4.1 Samples shall be allowed to air dry. Larger stones shall be removed by hand and the remainder sieved through a 10 mesh sieve.

Note - Material larger than the ten mesh shall be weighed as gravel and the percent by weight recorded on form to accompany sample. The minus ten mesh fraction is retained for the soils test and submitted to the Helena Laboratory.

5 Testing Procedures:

5.1 *Conductivity* - A measured volume of 15 ml. Of soil is placed in a 50 ml. Beaker. To this is added 30 ml. Of distilled water. The suspension is allowed to stand about one-half hour, being stirred several times during this period. Conductivity is measured using a pipette cell.

5.2 *Soil ph* - The suspension from conductivity measurement sample is decanted and discarded, saving the sediment for the ph measurement. The ph measurement is taken with a glass electrode ph meter.

6 ***Organic Matter -***

6.1 Reagents:

6.1.1 *$K_2 CR_2 O_7$, 1.0 N* - Dissolve exactly 49.04 GMS. $K_2 CR_2 O_7$ in distilled water and dilute to one liter.

6.1.2 *$Fe(NH_4)_2 (SO_2)$, approximately 0.5 N* - Dissolve 200 gms. $FE(NH_4)_2(SO_4)_2 6H_2O$ in 800 ml. Distilled water containing 20 ml. H_2SO_4 and dilute to one liter.

6.1.3 *Ferroin indicator* - 0.025 M solution purchased ready for use.

6.2 Procedure:

5.2.1 Place 1 gm of soil in a 250 ml. Erlenmeyer flask. Add 10 ml. Potassium dichromate with an automatic pipette. Add 20 ml. Conc. Sulfuric acid from a burette. Mix and let stand 10 minutes. Dilute with 70 ml. Distilled water added from a burette. Titrate the excess dichromate with ferrous ammonium sulfate. At the end point, the ferroin changes from blue to red. Run a blank using dichromate and acid, but no soil. The blank titration should be between 19.5 and 20.5 ml.

$$\% \text{ O. M.} = \frac{\text{BLANK} - \text{TITRATION}}{3}$$

Note - If the titration is less than 5.0, the soil is re-analyzed using ½ gm. sample and is divided by 1.5.

References:

Conductivity and pH: *Montana Agriculture Experiment Station, Plant and Soil Science Department, Circular No. 50 July 1968, Bozeman, MT*

Organic Matter: *Jackson, M.L. , Soil Chemical Analysis. pp. 219-221, Prentiss-Hall, Inc., 1958.*

METHODS OF SAMPLING AND TESTING
MT 413-04
INSPECTION OF FENCING MATERIAL

1 Scope:

1.1 This method is intended to cover the inspection and testing of fencing materials.

2 Referenced Documents:

2.1 ***ASTM:***
A 116 Specifications for Zinc-Coated (Galvanized) Steel Woven Wire Fence Fabric
A 121 Specifcations for Zinc-Coated (Galvanized) Steel Barbed Wire

2 General Information:

2.1 Material may be inspected and stored. Acceptable material must be identified by tagging or marking until used.

2.2 Visual inspection of mesh, posts and other parts shall be made for workmanship, dimension, condition of galvanizing and freedom from defects in accordance with specifications. Galvanizing shall be checked for excessive roughness, blisters, sal ammoniac spots, bruises, and flaking. Care and judgment must be exercised in making this inspection. Weave and finish (knuckling or barbed) of mesh shall be checked for compliance with specifications.

2.3 If gates are included in the order the design, general workmanship, dimensions, and condition of galvanizing shall be checked for conformance with specifications and applicable drawings. Welded connections shall be inspected to see that they have been cleaned and regalvanized or painted with approved paint. Whenever practical, materials used and galvanizing procedure shall be checked for compliance with specifications. Observing the fabrication when feasible will be helpful in this regard.

2.4 Samples shall be submitted to the Materials Bureau accompanied by completed Lab. Form No. 45.

2.5 Upon completion of a project, the Project Manager shall submit a report to the Materials Bureau showing the quantity of each type of material inspected and sampled.

2.6 As a guide to the inspector, all applicable specifications for fencing materials can be found in Montana Standard Specification for Road and Bridge Construction, Section 712.

3 Chain Link:

3.1 *Miscellaneous Fittings, Hardware, Wire Ties, and Tension Wire* - All miscellaneous fittings, hardware, wire fabric ties, wire ties, hot rings, and tension wire furnished for use in conjunction with zinc-coated steel fabric, or with aluminum-coated steel fabric, shall be of zinc-coated steel wire, and those furnished for use in conjunction with aluminum alloy fabric shall be of aluminum alloy wire.

3.2 *Marking* - Each roll of fabric shall carry a tag showing the kind of base metal, kind of coating, class of coating, the gage of the wire, the length of fencing in the roll, and the name or mark of the manufacturer. Posts, wire, and other fittings shall be identified as to the manufacturer, kind of base metal, class of coating, and other pertinent data sufficient for proper identification as to apparent conformance to specified quality requirements.

3 **Chain Link:** (continued)

3.3 *Sampling* - For purpose of tests, one roll from every 50 rolls for each project shall be selected at random. A one-foot length of fencing shall be cut from the end of the sample roll. If any test specimen shows defects or develops flaws, two additional specimen shall be cut from two additional rolls and tested, both of which shall meet the requirements in every respect.

4 **Woven Wire:**

4.1 *Joints and Workmanship* - Splicing of individual line wires by means of wrap joint or an electric butt weld is permitted. The maximum number of line wire spices or joints shall not exceed one-half of the number of line wires in any 2- rod roll of fence. Such splices or joints shall be made in a workmanlike manner. The woven wire fencing shall have uniformly wrapped joints and all stay wires shall be properly spaced and substantially perpendicular to the line wires.

4.2 *Packing and Marking* - Each roll of wire fencing shall be tightly rolled and firmly tied. Each roll shall carry a tag showing the style of fence, the length of fencing in the roll, class of coating, ASTM designation A 116, and the name or mark of the manufacturer.

4.3 *Sampling* - For purpose of testing, one roll of fencing from every 50 rolls for each project shall be selected at random. A three-foot length of fencing shall be cut from the end of the sample roll to include at least three of the vertical (stay) wires.

4.4 *Retests* - Should one or more of the test specimens from a sample roll of fence fabric fail the weight-of-coating test, or the breaking strength test, the lot shall be subjected to retests. For retest purposes, four additional rolls for each 50 rolls offered shall be sampled. The lot size then becomes 50.

5 **Barbed Wire:**

5.1 *Joints and Workmanship* - Splicing or individual strand wires by means of a wrap joint or an electric butt weld is permitted. Not more than three splices or joints shall exist in any 80 rod spool of barbed wire. Such splices or joints shall be made in a workmanlike manner. The strands shall be uniformly twisted and the barbs shall be sharp, well formed, tightly wrapped and accurately spaced.

5.2 *Inspection* - Gage of wire and barbs shall be checked, as well as the spacing of barbs and whether barbs are the type specified.

5.3 *Packing and Marking* - Each spool of barbed wire shall be compactly wound and fastened. Each spool shall be legibly marked with the style of barbed wire, class of coating, length, ASTM designation A 121, and name or mark of the manufacturer.

5.4 *Sampling* - For the purpose of testing, one spool from every 50 spools for each project shall be selected at random. At least 25 feet of barbed wire shall be cut from the end of the spool to provide material for testing. One sample of each strand wire shall be taken for testing.

5.5 *Retests* - Should one or more of the individual wire specimens fail the coating weight, break strength, barb or spacing tests, the lot shall be subject to retesting. For retest purposes, four additional spools of barbed wire for each 50 spools offered shall be sampled. The lot size then becomes 50, except this lot size may vary slightly to accommodate pallet count when the barbed wire is palletized. 5.5.1 and 5.5.2 state sample amount and length.

5.5.1 Retesting for coating and break strength: four - 4 ft lengths.

5.5.2 Retesting for barbs and barb spacing: four - 25 ft lengths

6 Hardware for Barbed or Woven Wire:

6.1 *Inspection* - Stay wires, brace wires, tie wires, and wire clamps shall be inspected for gage, condition of galvanizing and compliance with specifications. Any tendency of coating to flake off when wire is manipulated should be observed and noted.

7 Metal Posts for Barbed or Woven Wire:

7.1 *Inspection* - Metal posts shall be checked for compliance with dimensions.

7.2 *Sampling* - One post from every 400 posts for each project shall be selected at random.

8 Wood Fence Posts:

8.1 *Inspection* - Wood fence posts shall be checked for dimensions and freedom from defects, such as knots, shakes, splits, or other weakening defects for conformance with specifications. They shall be cleanly peeled with all the inner bark removed in order to permit adequate penetration of the treating solution.

METHODS OF SAMPLING AND TESTING
MT 414-04
METHOD OF ACCEPTANCE FOR REINFORCING STEEL

1 Scope:

1.1 The procedure set forth in this method will be followed for the acceptance of all reinforcing steel. The acceptance will be based on certain documents and random sampling.

2 Referenced Documents:

2.1 ***AASHTO:***
M 31 Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

ASTM:
A 615 Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

3 Required Documents:

3.1 For each shipment of reinforcing steel delivered to the project, the contractor shall furnish two copies each of the following documents to the Project Manager:

3.1.1 Shipping invoice that shows the weight of all the steel in the shipment.

Note 1 - In the event the steel does not meet the specification requirements, a copy of the manufacturer's invoiced price per pound for this material must be provided.

32.1.2 A signed and dated contractors Certificate of Compliance (Form 406).

3.2 A shipment shall consist of the entire amount of reinforcing steel in each truckload delivered to the project. When a shipment is made by railroad, each 20 tons or fraction thereof will be considered a shipment.

3.3 The Project Manager will retain one set of the documents shown above for his files. The other set will be forwarded to the Materials Bureau after the Project Manager has indicated on the invoice the method by which the steel was accepted. One of the following statements, together with the Project Manager's signature, will be shown on the invoice sent to Helena:

3.3.1 *"Shipment accepted on Form 46 and Form 406, no sample taken."*

3.3.2 *"Shipment accepted on Form 46 and Form 406 and acceptable test results."*

4 Random Sample Requirement:

4.1 In addition to the required documents, a minimum random sampling procedure will be adopted.

4.1.1 As shipments of steel arrive on the project, it will be the responsibility of the Project Manager to decide how many samples, if any, he will take and when and where they will be taken. Sampling will be done by the contractor as directed by the Project Manager in accordance with MT-601, using table 1 as a guide to indicate the minimum number of samples to be taken.

4.1.2 The following are locations in the structure where reinforcing steel samples may be taken, or the remaining portion of the sampled bar may be placed, without adverse effect on the structure. The Bridge Bureau must be contacted if clarification is required on the location of any sample bar.

4 Random Sample Requirement: (continued)

4.1.2.1 *Footing* - The outermost bar in the mat may be sampled. The portion of the bar remaining shall be centered in the footing and used as is.

4.1.2.2 *Column* - The bar nearest the centerline of bent at centerline of structure may be sampled. The sample shall be taken from the top end. The remaining portion of the bar may be used as is.

4.1.2.3 *Slab* - Transverse Steel - Take sample from bar in bottom layer. Center remaining portion of bar between curbs.

4.1.2.4 *Slab* - Longitudinal Steel - Take sample from any line of bars in bottom of slab adjacent to edge of a beam at the end of slab.

4.1.2.5 *Curb* - No sample need be taken.

4.1.2.6 *Bent Cross Beam* - The center bar in bottom layer at bottom of beam may be sampled. Center remaining portion of bar between columns.

4.1.2.7 *T Type Pier Cap* - The center bar in bottom layer at top of cap may be sampled. Center remaining portion of bar over column.

4.1.2.8 If re-sampling under paragraph 5.1.1.1 becomes necessary because of a failure, it will be necessary for the contractor to replace the sampled portion plus the required lap length.

4.1.3 Samples taken will be forwarded immediately to the Materials Bureau for testing in accordance with ASTM A 615 or AASHTO M 31.

4.1.4 The shipment under test shall be kept separate from the other steel on the project until test results have been received.

4.1.5 Steel taken for the purpose of sampling may have to be replaced in the structure. When replacement is necessary it shall be done by the contractor at no cost to the State.

5 American Made Materials:

5.1 No steel will be accepted if it does not carry permanent mill-imprinted markings denoting that it is American made material.

6 Failing Steel:

6.1 In case there is a failure in any size tested under this random sampling procedure, the steel may be rejected in accordance with 6.1.1 or, a price reduction will be assessed in accordance with 6.1.2.

6.1.1 The failing steel may be ordered removed and replaced at no cost to the State if either of the two check samples fail as described in paragraph 6.1.1.1, below.

6.1.1.1 In the event that a sample of reinforcing steel fails, two additional samples representing the sample that failed may be submitted. Both of the check samples must meet specifications before the shipment will be accepted without price reduction.

6.1.2 If the Bridge Engineer determines that the steel is usable, a price reduction will be assessed against the contractor. The price reduction will be calculated using the following formula:

$P = A \times B$ where:

6 **Failing Steel:** (continued)

A = total invoice price of reinforcing steel in the lot.*

B = 10%, 20% or 30% dependent upon departure from specifications. The value to be used shall be determined by the Bridge Engineer.

P = Price reduction for the Lot.

* A lot is defined as all of the bars of one bar number and pattern of deformation contained in an individual shipment.

7 **Standard Weights, Diameters and Number Designations:**

7.1 The standard weights and diameters of deformed reinforcing bars and their number designations shall be those listed in Table 1.

7.1.1 The three minimum yield levels of bars are: 40,000 psi; 60,000 psi; and 75,000 psi, designated as Grade 40, Grade 60, and Grade 75, respectively.

7.1.2 The nominal dimensions of a deformed bar are equivalent to those of a plain round bar having the same weight per foot as the deformed bar.

7.1.3 Bar numbers are based on the number of eighths of an inch included in the nominal diameter of the bars.

TABLE 1
English Version

Bar Size	Nominal Dia. Inches	Wt. Lb. Per Ft.	Minimum Sampling Frequency per Project
3	.375	.376	No sample for less than 2 tons 1 sample for ea. 5 tons or fraction
4	.500	.668	No sample for less than 5 tons 1 sample for ea. 40 tons or fraction
5	.625	1.043	No sample for less than 5 tons 1 sample for ea. 40 tons or fraction
6	.750	1.502	No sample for less than 5 tons 1 sample for ea. 85 tons or fraction
7	.875	2.044	No sample for less than 5 tons 1 sample for ea. 85 tons or fraction
8	1.000	2.670	No sample for less than 10 tons 1 sample for ea. 150 tons or fraction
9	1.128	3.400	No sample for less than 10 tons 1 sample for ea. 150 tons or fraction
10	1.270	4.303	No sample for less than 10 tons 1 sample for ea. 240 tons or fraction
11	1.410	5.313	No sample for less than 10 tons 1 sample for ea. 240 tons or fraction
14	1.693	7.650	One sample
18	2.257	13.600	One sample

TABLE 1
Metric Version

Bar Size	Nominal Dia. mm	Wt. Kg/m	Minimum Sampling Frequency per Project
10	9.5	0.560	No sample for less than 2 metric tons (t) 1 sample for ea. 5 metric tons (t)or fraction
13	12.7	0.560	No sample for less than 5 metric tons (t) 1 sample for ea. 36 metric tons (t)or fraction
16	15.69	1.552	No sample for less than 5 metric tons (t) 1 sample for ea. 36 metric tons (t)or fraction
19	19.1	2.235	No sample for less than 5 metric tons (t) 1 sample for ea. 77 metric tons (t)or fraction
22	22.2	3.042	No sample for less than 5 metric tons (t) 1 sample for ea. 77 metric tons (t)or fraction
25	25.4	3.973	No sample for less than 9 metric tons (t) 1 sample for ea. 136 metric tons (t)or fraction
29	28.7	5.060	No sample for less than 9 metric tons (t) 1 sample for ea. 136 metric tons (t)or fraction
32	32.3	6.404	No sample for less than 9 metric tons (t) 1 sample for ea. 218 metric tons (t)or fraction
36	35.8	7.907	No sample for less than 9 metric tons (t) 1 sample for ea. 218 metric tons (t)or fraction
43	43.0	11.38	One sample
57	57.3	20.24	One sample

METHODS OF SAMPLING AND TESTING
MT 416-04
PROCEDURE FOR SELECTING SAMPLING LOCATIONS BY RANDOM SAMPLING TECHNIQUE

1 Scope:

1.1 The following is a method of selecting sampling locations of various materials from roadways and trucks hauling asphalt mixture.

2 Definitions:

2.1 *Lot* - a quantity of material that one desires to control. It may represent a day's production, a specified tonnage, a specified number of truckloads, a specified time period during production.

2.2 *Sample* - a segment of a lot chosen to represent the total lot. It may represent any number of sub-samples.

2.3 *Sub-sample* - a segment of a sample, taken from a unit of the lot, i.e., specified ton, a specified time, a specified truckload.

2.4 *Sample Unit* - a portion of sub-sample taken from a unit of a lot and combined with one or more other sample units to make up a sub-sample.

3 Selecting Sampling Locations from Roadways:

3.1 Table X-1, pages 5 to 8, contains random numbers for the general sampling procedures. To use this table for selecting locations for collecting samples, the following steps are necessary:

3.1.1 Determine the number of sampling locations within a section by selecting the maximum average longitudinal distance desired between samples and dividing the length of the section by the maximum average longitudinal distance.

3.1.2 Select a column of random numbers in Table X-1 by placing 28 one inch square pieces of cardboard, numbered 1 thru 28, into a container, shaking them to get them thoroughly mixed, and drawing out one.

3.1.3 Go to the column of Random Numbers identified with the number drawn from the container. In sub-column A, locate all numbers equal to and less than the number of sampling locations desired.

3.1.4 Multiply the total length of the section by the decimal values in sub-column B, found opposite the numbers located in sub-column A. Add the results to the station number at the beginning of the section to obtain the station of the sampling location.

3.1.5 Multiply the total width of the pavement in the section by the decimal values found in sub-column C, opposite the numbers in sub-column A, to obtain the offset distance from the left edge of the pavement to the sampling location.

4 Example:

4.1 Given: A completed plant mix surfacing project, 24 feet wide, 16,500 feet long, running from Station 100+00 to 265+00.

4 **Example:** (continued)

4.1.1 For sampling purposes it is desired to take one pavement core for each 2-lane mile. The number of sampling locations for this section, then are:

$$\frac{16,500}{5,280} = 3.1 = 3 \text{ locations}$$

4.1.2 The number 16 drawn from a container identifies this column of random numbers in Table X-1 to use.

4.1.3 The numbers selected from column 16 are:

Col. A	Col. B	Col. C
3	.548	.688
2	.739	.298
1	.331	.925

4.1.4 Station number of sampling location:

Length of Section, Feet	X	Col. B	=	Distance from Beginning of Section, Feet	+	Station at Beginning of section	=	Station Number of Sampling Location
16,500		.548		9042		100+00		190+42
16,500		.739		12190		100+00		221+90
26,500		.331		546		100+00		105+46

4.1.5 Offset distance from left edge of pavement to sampling location, feet.

Width of Pavement, Feet	x	Col. C	=	Offset Distance From Left Edge of Pavement to Sampling Location, Feet
24		.688		16.5
24		.298		7.2
24		.925		22.2

4.1.6 Sampling locations are:

Station Number	Distance From Left Edge, Feet
190+42	16.5
221+90	7.2
105+46	22.2

5 **Selecting Sampling Locations in Trucks Hauling Asphalt Mixture:**

5.1 In this procedure, the following steps are necessary to select the sampling locations:

5 **Selecting Sampling Locations in Trucks Hauling Asphalt Mixture:** (continued)

5.1.1 Select lot size--it can be time (hours), an average day's production (tons), a selected tonnage [example: 2,000 tons (1815 mg)] or a selected number of truckloads. (A lot size of a day's production is recommended for this procedure as being convenient and easy to randomize.)

5.1.2 Select the number of samples desired per lot. One sample per lot, made up of *four* sub-samples, is the minimum recommended.

5.1.3 Select the number of locations in each truckload from which sampling units of asphalt mixtures will be taken to combine into one sub-sample. *Two* sampling units per sub-sample are recommended.

5.1.4 Assign each truckload of mixture in the lot a number, beginning with 1 for the first truckload and number them successively to the highest number in the lot. Find the truckload numbers for sampling by the following procedure:

5.1.4.1 Place consecutively numbered [1 through _____ one-inch (25 mm)] square pieces of cardboard, equal to the number of truckloads in the lot, into a container (such as a bowl). Mix them thoroughly before each drawing.

5.1.4.2 Draw a number of cardboard squares from the container equal to the number of sub-samples desired for the lot. The numerals on the cardboard squares will be the truckloads to be sampled.

5.1.5 Choose for each sub-sample desired the location in the truckload for each of the sampling units. Use the following steps:

5.1.5.1 Divide the truck beds into equal quadrants and number them 1 through 4 in any order desired.

5.1.5.2 Place four consecutively numbered [1 through 4, one-inch (25 mm)] square pieces of cardboard into a container (such as a bowl). Mix them thoroughly before each drawing.

5.1.5.3 Draw out an amount of cardboard squares equal to the number of sample units desired. The numerals on each square drawn represent the quadrants from which the sample will be taken. Replace the cardboard squares and repeat this step for each sample unit of each sub-sample to be taken.

Note - The principles involved may be applied to any other type of sampling of various materials which use the measurements of time, quantity, depth or other distinctive measurements of a construction phase. There are other random methods such as using a watch or deck of cards that are readily adaptable to obtaining roadway samples and they may be used provided the full benefit of obtaining random samples is accomplished.

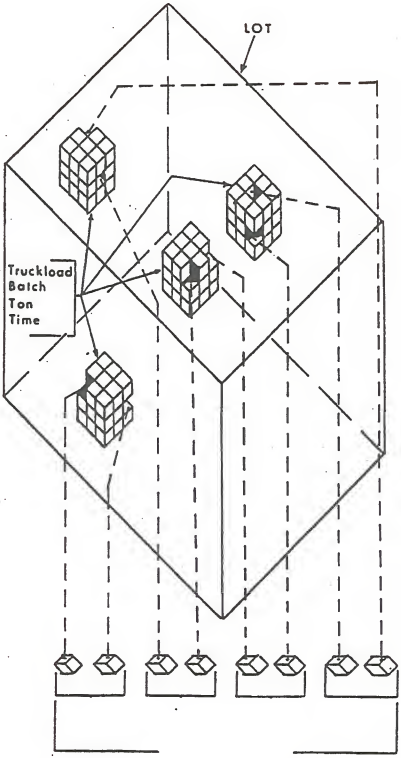


FIGURE 1—Schematic diagram illustrating *Lot, Sample, Subsample, and Sample Unit.*

TABLE X–1–RANDOM NUMBERS FOR GENERAL SAMPLING PROCEDURE

Col. No. 1			Col. No. 2			Col. No. 3			Col. No. 4			Col. No. 5			Col. No. 6			Col. No. 7		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
15	.033	.576	05	.048	.879	21	.013	.220	18	.089	.716	17	.024	.863	30	.030	.901	12	.029	.386
21	.101	.300	17	.074	.156	30	.036	.853	10	.102	.330	24	.060	.032	21	.096	.198	18	.112	.284
23	.129	.916	18	.102	.191	10	.052	.746	14	.111	.925	26	.074	.639	10	.100	.161	20	.114	.848
30	.158	.434	06	.105	.257	25	.061	.934	28	.127	.840	07	.167	.512	29	.133	.388	03	.121	.656
24	.177	.397	28	.179	.447	29	.062	.507	24	.132	.271	28	.194	.776	24	.138	.062	13	.178	.640
11	.202	.271	26	.187	.844	18	.087	.887	19	.285	.899	03	.219	.166	20	.168	.564	22	.209	.421
16	.204	.012	04	.188	.482	24	.105	.849	01	.326	.037	29	.264	.284	22	.232	.953	16	.221	.311
08	.208	.418	02	.208	.577	07	.139	.159	30	.334	.938	11	.282	.262	14	.259	.217	29	.235	.356
19	.211	.798	03	.214	.402	01	.175	.641	22	.405	.295	14	.379	.994	01	.275	.195	28	.264	.941
29	.233	.070	07	.245	.080	23	.196	.873	05	.421	.282	13	.394	.405	06	.277	.475	11	.287	.199
07	.260	.073	15	.248	.831	26	.240	.981	13	.451	.212	06	.410	.157	02	.296	.497	02	.336	.992
17	.262	.308	29	.261	.087	14	.255	.374	02	.461	.023	15	.438	.700	26	.311	.144	15	.393	.488
25	.271	.180	30	.302	.883	06	.310	.043	06	.487	.539	22	.453	.635	05	.351	.141	19	.437	.655
06	.302	.672	21	.318	.088	11	.316	.653	08	.497	.396	21	.472	.824	17	.370	.811	24	.466	.773
01	.409	.406	11	.376	.936	13	.324	.585	25	.503	.893	05	.488	.118	09	.388	.484	14	.531	.014
13	.507	.693	14	.430	.814	12	.351	.275	15	.594	.603	01	.525	.222	04	.410	.073	09	.562	.678
02	.575	.654	27	.438	.676	20	.371	.535	27	.620	.894	12	.561	.980	25	.471	.530	06	.601	.675
18	.591	.318	08	.467	.205	08	.409	.495	21	.629	.841	08	.652	.508	13	.486	.779	10	.612	.859
20	.610	.821	09	.474	.138	16	.445	.740	17	.691	.583	18	.668	.271	15	.515	.867	26	.673	.112
12	.631	.597	10	.492	.474	03	.494	.929	09	.708	.689	30	.736	.634	23	.567	.798	23	.738	.770
27	.651	.281	13	.499	.892	27	.543	.987	07	.709	.012	02	.763	.253	11	.618	.502	21	.753	.614
04	.661	.953	19	.511	.520	17	.625	.171	11	.714	.049	23	.804	.140	28	.636	.148	30	.758	.851
22	.692	.089	23	.591	.770	02	.699	.073	23	.720	.695	25	.828	.425	27	.650	.741	27	.765	.563
05	.779	.346	20	.604	.730	19	.702	.934	03	.748	.413	10	.843	.627	16	.711	.508	07	.780	.534
09	.787	.173	24	.654	.330	22	.816	.802	20	.781	.603	16	.858	.849	19	.778	.812	04	.818	.187
10	.818	.837	12	.728	.523	04	.838	.166	26	.830	.384	04	.903	.327	07	.804	.675	17	.837	.353
14	.895	.631	16	.753	.344	15	.904	.116	04	.843	.002	09	.912	.382	08	.806	.952	05	.854	.818
26	.912	.376	01	.806	.134	28	.969	.742	12	.884	.582	27	.935	.162	18	.841	.414	01	.867	.133
28	.920	.163	22	.878	.884	09	.974	.046	29	.926	.700	20	.970	.582	12	.918	.114	08	.915	.538
03	.945	.140	25	.939	.162	05	.977	.494	16	.951	.601	19	.973	.327	03	.992	.399	25	.975	.584

MT 416-04-060104

(Continued) TABLE X—1—RANDOM NUMBERS FOR GENERAL SAMPLING PROCEDURE

Col. No. 8			Col. No. 9			Col. No. 10			Col. No. 11			Col. No. 12			Col. No. 13			Col. No. 14		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
09	.042	.071	14	.061	.935	26	.038	.023	27	.074	.779	16	.073	.987	03	.033	.091	26	.035	.175
17	.141	.411	02	.065	.097	30	.066	.371	06	.084	.396	23	.078	.056	07	.047	.391	17	.089	.363
02	.143	.221	03	.094	.228	27	.073	.876	24	.098	.524	17	.096	.076	28	.064	.113	10	.149	.681
05	.162	.899	16	.122	.945	09	.095	.568	10	.133	.919	04	.153	.163	12	.066	.360	28	.238	.075
03	.285	.016	18	.158	.430	05	.180	.741	15	.187	.079	10	.254	.834	26	.076	.552	13	.244	.767
28	.291	.034	25	.193	.469	12	.200	.851	17	.227	.767	06	.284	.628	30	.087	.101	24	.262	.366
08	.369	.557	24	.224	.572	13	.259	.327	20	.236	.571	12	.305	.616	02	.127	.187	08	.264	.651
01	.436	.386	10	.225	.223	21	.264	.681	01	.245	.988	25	.319	.901	06	.144	.068	18	.285	.311
20	.450	.289	09	.233	.838	17	.283	.643	04	.317	.291	01	.329	.212	25	.202	.674	02	.340	.131
18	.455	.789	20	.290	.120	23	.363	.063	29	.350	.911	08	.416	.372	01	.247	.025	29	.353	.478
23	.488	.715	01	.297	.242	20	.364	.366	26	.380	.104	13	.432	.536	23	.253	.323	06	.359	.270
14	.496	.276	11	.337	.760	16	.395	.363	28	.425	.864	02	.489	.827	24	.320	.651	20	.387	.248
15	.503	.342	19	.389	.064	02	.423	.540	22	.487	.526	29	.503	.787	10	.328	.365	14	.392	.694
04	.515	.693	13	.411	.474	08	.432	.736	05	.552	.311	15	.518	.717	27	.338	.412	03	.408	.077
16	.532	.112	20	.447	.893	10	.476	.468	14	.564	.357	28	.524	.998	13	.356	.991	27	.440	.280
22	.557	.357	22	.478	.321	03	.508	.774	11	.572	.306	03	.542	.352	16	.401	.792	22	.461	.830
11	.559	.620	29	.481	.993	01	.601	.417	21	.594	.197	19	.585	.462	17	.423	.117	16	.527	.003
12	.650	.216	27	.562	.403	22	.687	.917	09	.607	.524	05	.695	.111	21	.481	.838	30	.531	.486
21	.672	.320	04	.566	.179	29	.697	.862	19	.650	.572	07	.733	.838	08	.560	.401	25	.678	.360
13	.709	.273	08	.603	.758	11	.701	.605	18	.664	.101	11	.744	.948	19	.564	.190	21	.725	.014
07	.745	.687	15	.632	.927	07	.728	.498	25	.674	.428	18	.793	.748	05	.571	.054	05	.797	.595
30	.780	.285	06	.707	.107	14	.745	.679	02	.697	.674	27	.802	.967	18	.587	.584	15	.801	.927
19	.845	.097	28	.737	.161	24	.819	.444	03	.767	.928	21	.826	.487	15	.604	.145	12	.836	.294
26	.846	.366	17	.846	.130	15	.840	.823	16	.809	.529	24	.835	.832	11	.641	.298	04	.854	.982
29	.861	.307	07	.874	.491	25	.863	.568	30	.838	.294	26	.855	.142	22	.672	.156	11	.884	.928
25	.906	.874	05	.880	.828	06	.878	.215	13	.845	.470	14	.861	.462	20	.674	.887	19	.886	.832
24	.919	.809	23	.931	.659	18	.930	.601	08	.855	.524	20	.874	.625	14	.752	.881	07	.929	.932
10	.952	.535	26	.960	.365	04	.934	.827	07	.867	.718	30	.929	.036	09	.774	.560	09	.932	.206
06	.961	.504	21	.978	.194	28	.963	.004	12	.881	.722	09	.935	.582	29	.921	.752	01	.970	.692
27	.969	.811	12	.982	.183	19	.988	.020	23	.937	.872	22	.947	.797	04	.959	.099	23	.973	.082

MT 416-04-060104

(Continued) TABLE X—1—RANDOM NUMBERS FOR GENERAL SAMPLING PROCEDURE

Col. No. 15			Col. No. 16			Col. No. 17			Col. No. 18			Col. No. 19			Col. No. 20			Col. No. 21		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
15	.023	.979	19	.062	.588	13	.045	.004	25	.027	.290	12	.052	.075	20	.030	.881	01	.010	.946
11	.118	.465	25	.080	.218	18	.086	.878	06	.057	.571	30	.075	.493	12	.034	.291	10	.014	.939
07	.134	.172	09	.131	.295	26	.126	.990	26	.059	.026	28	.120	.341	22	.043	.893	09	.032	.346
01	.139	.230	18	.136	.381	12	.128	.661	07	.105	.176	27	.145	.689	28	.143	.073	06	.093	.180
16	.145	.122	05	.147	.864	30	.146	.337	18	.107	.358	02	.209	.957	03	.150	.937	15	.151	.012
20	.165	.520	12	.158	.365	05	.169	.470	22	.128	.827	26	.272	.818	04	.154	.867	16	.185	.455
06	.185	.481	28	.214	.184	21	.244	.433	23	.156	.440	22	.299	.317	19	.158	.359	07	.227	.277
09	.211	.316	14	.215	.757	23	.270	.849	15	.171	.157	18	.306	.475	29	.304	.615	02	.304	.400
14	.248	.348	13	.224	.846	25	.274	.407	08	.220	.097	20	.311	.653	06	.369	.633	30	.316	.074
25	.249	.890	15	.227	.809	10	.290	.925	20	.252	.066	15	.348	.156	18	.390	.536	18	.328	.799
13	.252	.577	11	.280	.898	01	.323	.490	04	.268	.576	16	.381	.710	17	.403	.392	20	.352	.288
30	.273	.088	01	.331	.925	24	.352	.291	14	.275	.302	01	.411	.607	23	.404	.182	26	.371	.216
18	.277	.689	10	.399	.992	15	.361	.155	11	.297	.589	13	.417	.715	01	.415	.457	19	.448	.754
22	.372	.958	30	.417	.787	29	.374	.882	01	.358	.305	21	.472	.484	07	.437	.696	13	.487	.598
10	.461	.075	08	.439	.921	08	.432	.139	09	.412	.089	04	.478	.885	24	.446	.546	12	.546	.640
28	.519	.536	20	.472	.484	04	.467	.266	16	.429	.834	25	.479	.080	26	.485	.748	24	.550	.038
17	.520	.090	24	.498	.712	22	.508	.880	10	.491	.203	11	.566	.104	15	.511	.313	03	.604	.780
03	.523	.519	04	.516	.396	27	.632	.191	28	.542	.306	10	.576	.659	10	.517	.290	22	.621	.930
26	.573	.502	03	.548	.688	16	.661	.836	12	.563	.091	29	.665	.397	30	.536	.853	21	.629	.154
19	.634	.206	23	.597	.508	19	.675	.629	02	.593	.321	19	.739	.298	25	.561	.837	11	.634	.908
24	.635	.810	21	.681	.114	14	.680	.890	30	.692	.198	14	.749	.759	09	.574	.599	05	.696	.459
21	.679	.841	02	.739	.298	28	.714	.508	19	.705	.445	08	.756	.919	13	.613	.762	23	.710	.078
27	.712	.366	29	.792	.038	06	.719	.441	24	.709	.717	07	.798	.183	11	.698	.783	29	.726	.585
05	.780	.497	22	.829	.324	09	.735	.040	13	.820	.739	23	.834	.647	14	.715	.179	17	.749	.916
23	.861	.106	17	.834	.647	17	.741	.906	05	.848	.866	06	.837	.978	16	.770	.128	04	.802	.186
12	.865	.377	16	.909	.608	11	.747	.205	27	.867	.633	03	.849	.964	08	.815	.385	14	.835	.319
29	.882	.635	06	.914	.420	20	.850	.047	03	.883	.333	24	.851	.109	05	.872	.490	08	.870	.546
08	.902	.020	27	.958	.856	02	.859	.356	17	.900	.443	05	.859	.935	21	.885	.999	28	.871	.539
04	.951	.482	26	.981	.976	07	.870	.612	21	.914	.483	17	.863	.220	02	.958	.177	25	.971	.369
02	.977	.172	07	.983	.624	03	.916	.463	29	.950	.753	09	.863	.147	27	.961	.980	27	.984	.252

MT 416-04-060104

(Continued) **TABLE X—1—RANDOM NUMBERS FOR GENERAL SAMPLING PROCEDURE**

Col. No. 22			Col. No. 23			Col. No. 24			Col. No. 25			Col. No. 26			Col. No. 27			Col. No. 28		
A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
12	.051	.032	26	.051	.187	08	.015	.521	02	.039	.005	16	.026	.102	21	.050	.952	29	.042	.039
11	.068	.980	03	.053	.256	16	.068	.994	16	.061	.599	01	.033	.886	17	.085	.403	07	.105	.293
17	.089	.309	29	.100	.159	11	.118	.400	26	.068	.054	04	.088	.686	10	.141	.624	25	.115	.420
01	.091	.371	13	.102	.465	21	.124	.565	11	.073	.812	22	.090	.602	05	.154	.157	09	.126	.612
10	.100	.709	24	.110	.316	18	.153	.158	07	.123	.649	13	.114	.614	06	.164	.841	10	.205	.144
30	.121	.744	18	.114	.300	17	.190	.159	05	.126	.658	20	.136	.576	07	.197	.013	03	.210	.054
02	.166	.056	11	.123	.208	26	.192	.676	14	.161	.189	05	.138	.228	16	.215	.363	23	.234	.533
23	.179	.529	09	.138	.182	01	.237	.030	18	.166	.040	10	.216	.565	08	.222	.520	13	.266	.799
21	.187	.051	06	.194	.115	12	.283	.077	28	.248	.171	02	.233	.610	13	.269	.477	20	.305	.603
22	.205	.543	22	.234	.480	03	.286	.318	06	.255	.117	07	.278	.357	02	.288	.012	05	.372	.223
28	.230	.688	20	.274	.107	10	.317	.734	15	.261	.928	30	.405	.273	25	.333	.633	26	.385	.111
19	.243	.001	21	.331	.292	05	.337	.844	10	.301	.811	06	.421	.807	28	.348	.710	30	.422	.315
27	.267	.990	08	.346	.085	25	.441	.336	24	.363	.025	12	.426	.583	20	.362	.961	17	.453	.783
15	.283	.440	27	.382	.979	27	.469	.786	22	.378	.792	08	.471	.708	14	.511	.989	02	.460	.916
16	.352	.089	07	.387	.863	24	.473	.237	27	.379	.959	18	.473	.738	26	.540	.903	27	.461	.841
03	.377	.648	28	.411	.776	20	.475	.761	19	.420	.557	19	.510	.207	27	.587	.643	14	.483	.095
06	.397	.769	16	.444	.999	06	.557	.001	21	.467	.943	03	.512	.329	12	.603	.745	12	.507	.375
09	.409	.428	04	.515	.993	07	.610	.238	17	.494	.225	15	.640	.329	29	.619	.895	28	.509	.748
14	.465	.406	17	.518	.827	09	.617	.041	09	.620	.081	09	.665	.354	23	.623	.333	21	.583	.804
13	.499	.651	05	.539	.620	13	.641	.648	30	.623	.106	14	.680	.884	22	.624	.076	22	.587	.993
04	.539	.972	02	.623	.271	22	.664	.291	03	.625	.777	26	.703	.622	18	.670	.904	16	.689	.339
18	.560	.747	30	.637	.374	04	.668	.856	08	.631	.790	29	.739	.394	11	.711	.253	06	.727	.298
26	.575	.892	14	.714	.364	19	.717	.232	12	.715	.599	25	.759	.386	01	.790	.392	04	.731	.814
29	.756	.712	15	.730	.107	02	.776	.504	23	.782	.093	24	.803	.602	04	.813	.611	08	.807	.983
20	.760	.920	19	.771	.552	29	.777	.548	20	.810	.371	27	.842	.491	19	.843	.732	13	.833	.757
05	.847	.925	23	.780	.662	14	.823	.223	01	.841	.726	21	.870	.435	03	.844	.511	19	.896	.464
25	.872	.891	10	.924	.888	23	.848	.264	29	.862	.009	28	.906	.367	30	.858	.299	18	.916	.384
24	.874	.135	12	.929	.204	30	.892	.817	25	.891	.873	23	.948	.367	09	.929	.199	01	.948	.610
08	.911	.215	01	.937	.714	28	.943	.190	04	.917	.264	11	.956	.142	24	.931	.263	11	.976	.799
07	.946	.065	25	.974	.398	15	.975	.962	13	.958	.990	17	.993	.989	15	.939	.947	24	.978	.633

MT 416-04-060104

METHODS OF SAMPLING AND TESTING
MT 417-04
PROCEDURE FOR REDUCING FIELD SAMPLES OF AGGREGATE TO TESTING SIZE
(Modified AASHTO T248)

1 Scope:

1.1 These methods cover the reduction of field samples of aggregate to the appropriate size for testing, and applies to fine aggregate (FA), coarse aggregate (CA), and mixes of the two, and employ techniques that are intended to minimize variations in measured characteristics between the test samples and the field sample.

Note 1 - Under certain circumstances, reduction in size of the field sample prior to testing is not recommended. Substantial differences between the selected test samples sometimes cannot be avoided, as for example, in the case of an aggregate having relatively few large size particles in the field sample. The laws of chance dictate that these few particles may be unequally distributed among the reduced size test samples. Similarly, if the test sample is being examined for certain contaminants occurring as a few discrete fragments in only small percentages, caution should be used in interpreting results from the reduced size test sample. Chance inclusion or exclusion of only one or two particles in the selected sample may importantly influence interpretation of the characteristics of the field sample. In these cases, the entire field sample should be tested.

2 Referenced Documents:

2.1 ***AASHTO:***
T248 Reducing Samples of Aggregate to Testing Size

MT Manual:
MT-201 Sampling Roadway Materials
MT-204 Specific Gravity and Absorption of Fine Aggregate

3 Selection of Method:

3.1 *Fine Aggregates* - Field samples of fine aggregate (FA) that are drier than the saturated-surface-dry (SSD) condition (Note 2) shall be reduced to test size by a mechanical splitter according to Method A. Field samples of FA that are wetter than SSD may be reduced to test size by quartering according to Method B, or the entire field sample may be dried to drier than SSD, using temperatures that do not exceed those specified for any of the tests contemplated, and then reduced to test sample size using Method A.

3.1.1 Field samples of fine aggregate wetter than SSD may be reduced to testing size by treatment as a miniature stockpile as described in Method C.

3.1.2 If a moist field sample is very large, a preliminary split may be made by quartering according to Method B to reduce the sample to not less than 5000 g, the portion obtained is then dried and reduced to test sample size using Method A.

3.1.3 Mixtures of FA and CA that are wetter than SSD shall be reduced to test sample size according to Method B.

Note 2 - The method of determining the saturated-surface-dry condition is described in paragraph 5.2 of MT-204. As a quick approximation, if the fine aggregate will retain its shape when molded in the hand, it may be considered to be wetter than saturated-surface-dry.

3.2 *Coarse Aggregate* - Use of a mechanical splitter in accordance with Method A is preferred, however, the field sample may be reduced by quartering in accordance with Method B.

4 Field Sample Size:

4.1 The size of the field sample shall conform to paragraph 3 of MT-201.

METHOD A - MECHANICAL SPLITTER

5 Apparatus:

5.1 *Sample Splitter* - Sample splitters shall have an even number of equal width chutes, but not less than a total of eight for coarse aggregate or twelve for fine aggregate which discharge alternately to each side of the splitter. The minimum width of the individual chutes shall be approximately 50 percent larger than the largest particles in the sample to be split (Table 1). The splitter shall be equipped with two receptacles to hold the two halves of the sample following splitting. It shall also be equipped with a hopper or straight-edged pan, which has a width equal to or slightly less than the overall width of the assembly of chutes by which the sample may be fed at a controlled rate to the chutes. The splitter and accessory equipment shall be so designed that the sample will flow smoothly without restriction or loss of material.

Table 1

Size Passing - 100%	Splitter Opening
2 in.	3 in. or 6 bars
1½ in.	2¼ in. or 6 bars
1 in.	1½ in. or 3 bars
¾ in.	1½ in. or 3 bars
½ in.	¾ in. or 2 bars
⅜ in.	9/16 in. or 2 bars
4M	½ in. or 1 bar

Each bar = ½ inch

Example - When splitting 1½ inch Crushed Base Course, the total sample would require 2¼ inches or 6 bars and the minus 4M would require ½ inch or 1 bar.

6 Procedure:

6.1 Place the field sample in the hopper or pan and uniformly distribute it from edge to edge, so that when it is introduced into the chutes, approximately equal amounts will flow through each chute. (Note 3). The rate at which the sample is introduced shall be such as to allow free flowing through the chutes into the receptacles below. Reintroduce the portion of the sample in one of the receptacles into the splitter as many times as necessary to reduce the sample to the size specified for the intended test. The portion of the material collected in the other receptacle may be reserved for reduction in size for other tests.

Note 3 - A sample splitter that has a hopper equipped with a dumping device may be filled and leveled with a straightedge prior to dumping into the chutes. A sample splitter that has a free-flowing hopper shall be filled by a container, which has a width equal to or slightly less than the overall width of the assembly of chutes. The side of the container shall be placed against the edge of the hopper and dumped in a single motion into the hopper. In no case shall the material be poured into the hopper from the end of the container, scoop, or shovel.

METHOD B - QUARTERING

7 Apparatus:

7.1 The apparatus shall consist of a straightedge, scoop, shovel, or trowel; a broom or brush; and a canvas blanket approximately 6 x 8 ft (2 x 2.5 m).

8 Procedure:

8.1 Place the field sample on a hard, clean, level surface where there will be neither loss of material nor the accidental addition of foreign material. Mix the material thoroughly by turning the entire sample over three times. With the last turning, shovel the entire sample into a conical pile by depositing each shovelful on top of the preceding one. Carefully flatten the conical pile to a uniform thickness and diameter by pressing down the apex with a shovel so that each quarter sector of the resulting pile will contain the material originally in it. The diameter should be approximately four to eight times the thickness. Divide the flattened mass into four equal quarters with a shovel or trowel and remove two diagonally opposite quarters, including all fine material, and brush the cleared spaces clean. Successively mix and quarter the remaining material until the sample is reduced to the desired size.

8.2 As an alternate method when the floor surface is uneven, the field sample may be placed on a canvas blanket and mixed with a shovel as described above or by alternately lifting each corner of the canvas and pulling it over the sample toward the diagonally opposite corner causing the material to be rolled. Flatten the pile as described in paragraph 8.1. Divide the sample as also described in paragraph 8.1 or if the surface beneath the blanket is uneven, insert a stick or pipe beneath the blanket and under the center of the pile, then lift both ends of the stick dividing the sample into two equal parts. Remove the stick leaving a fold of the blanket between the divided portions. Insert the stick under the center of the pile at right angles to the first division and again lift both ends of the stick, dividing the sample into four equal parts. Remove two diagonally opposite quarters, being careful to clean the fines from the blanket. The remaining two quarters shall be successively remixed and quartered until the sample is reduced to the desired size.

METHOD C - MINIATURE STOCKPILE SAMPLING

9 Apparatus:

9.1 The apparatus shall consist of a small sampling thief, small scoop, or spoon.

10 Procedure:

10.1 Place the field sample on a hard, clean, level, non-absorbent surface. Thoroughly mix the sample and form a miniature stockpile. Obtain a sample for each test by selecting at least five increments of material at random locations from the miniature stockpile, using any of the devices described in paragraph 9.

METHODS OF SAMPLINGB AND TESTING
MT 418-04
METHOD OF ACCEPTANCE FOR MISECLLANEOUS WELDED ITEMS
(MONTANA METHOD)

1 Scope:

1.1 This method is intended as a guide for the acceptance of miscellaneous, low stress carrying welded items. It does not cover any welding in connection with bridge related items.

2 Referenced Documents:

2.1 Montana Department of Transportation Detailed Drawings

3 Field Welding Acceptance:

3.1 The low stress carrying members listed in 3.1.1, 3.1.2, and 3.1.3 below can be approved by the field provided the welding has been done by a qualified welder in accordance with AWS D1.1 Current edition, Limited Thickness. In the event that field welding is necessary, contact the Bridge Bureau for welder qualification tests.

3.1.1 Trash guard racks (MDT Detailed Drawing No. 615-02) and median inlet covers (MDT Detailed Drawing No. 604-00).

3.1.2 Guardrail terminal section anchor plates (MDT Detailed Drawing No. 606-86).

3.1.3 Ladders, stairways, scale pit angles, grates, and miscellaneous items associated with weigh stations, rest areas, and observation points.

3 Acceptance Procedure:

4.1 The procedure listed in 4.1.1, 4.1.2, 4.1.3, and 4.1.4 below must be followed for the acceptance of welded items covered in this method.

4.1.1 A copy of the mill test results must accompany the material.

4.1.2 A copy of the welder qualification form or other verification must accompany the material.

4.1.3 The items must be visually inspected and the welds examined for appearance, size, undercut, and porosity.

4.1.4 Items 4.1.1 and 4.1.2 must be attached to the visual inspection report and submitted in the usual manner.

METHODS OF SAMPLING AND TESTING
MT 419-04
METHOD OF SAMPLING AND SIEVE ANALYSIS OF GLASS BEADS
(Modified ASTM D-1214)

1 Scope:

1.1 This method covers the procedure for sampling and sieve analysis of glass beads and submitting samples to the Materials Bureau.

2 Referenced Documents:

2.1 ***ASTM:***
D 1214 Test Method for Sieve Analysis of Glass Spheres

MT Manual:
MT 405 Wire Cloth Sieves for Testing Purposes
MT 417 Procedure for Reducing Field Samples to Testing Size

3 Apparatus:

3.1 *Sieves* – Standard 8 inch round brass sieves of the size specifies in the Standard Specifications and conforming to the provisions of MT-405.

3.2 *Balance* – The balance or scale shall have a capacity of at least 100 g. and a sensitivity of 0.05 g.

3.3 *Oven* – Capable of maintaining a constant temperature of 105 to 110 c.

3.4 *Sample Splitters* – Sample splitters of the type commonly used in the preparation of gravel samples and described in MT-417 .

3.5 *Sample Containers* - Clean new one quart non-corroding metal containers for shipment of the beads to the Materials Bureau.

4 Sampling Procedure:

4. 1 A representative of the Department will randomly select samples to represent each lot, rack, or batch in the shipment.

4.2 A sample splitter shall be used to select the representative samples from the material to be tested.

3.3 Two separate samples of approximately one quart each shall represent each lot, rack, or batch, up to 10, 000 lbs. (4540 Kg) and one sample for each additional 10, 000 lbs or fraction thereof.

5 Testing Procedure:

5.1 The one quart containers of beads shall be further reduced in size to approximately 50 g. in weight by means of the mechanical splitters. This sample shall be dried to a constant weight in the oven at 105 to 110 c.

5.2 The dried sample shall then be sieved by the hand method over the specified screens and weight retained on each screen recorded to the nearest 0.05 g.

4.3 Calculate the percent passing each specified screen to the nearest 0.5 percent.

METHOD OF SAMPLING AND TESTING
MT 420-04
PROCEDURE TO CHECK FOR LEAKS UNDER HYDROSTATIC PRESSURE

1 Scope:

1.1 This procedure is used to determine the degree of water tightness for corrugated metal irrigation or siphon pipe and couplers. This test is customarily performed at the fabrication plant, but can also be performed in the field.

2 Apparatus and Equipment:

2.1 Bulkheads shall consist of the following:

2.1.1 A two-foot section of corrugated steel pipe of the specific diameter to be tested. Pipe sections with helical corrugations shall be re-rolled at the outer ends to form at least two corrugations to fully accommodate band couplers.

2.1.2 Two squares pieces of 1/8 inch thick steel plate, with a dimension four inches greater than the diameter of the pipes to be tested.

2.1.3 Four lengths of 2 inch x 2 inch x ¼ inch steel angles to be used as braces with a length equal to the dimension of the plates.

2.1.4 One – 3 inch galvanized steel elbow.

2.1.5 One – 3 inch galvanized cap with a ¾ inch threaded hole at center.

2.1.6 One – ¾ inch, or longer, gate valve to accommodate a water hose.

2.1.7 Two full length section of culvert.

2.1.8 Three approved band couplers with appropriate gaskets.

2.1.9 2 inch x 4 inch wood bracing blocks 3 feet in length.

2.2 The bulkheads consist of two 2-foot sections of corrugated steel pipe, of the diameter of the pipe to be tested, to which a braced 1/8 inch square plate has been welded to one end. One bulkhead is fitted with a 3 inch galvanized elbow. The elbow is welded vertically to the top of the plate. The horizontal leg of the elbow must be located directly below the trough of the culvert corrugation to prevent air entrapment (See fig. 1).

2.3 A 3 inch removable, galvanized filler cap with ¾ inch dia. hole at center is to accommodate a standpipe for observing the static pressure head applied (see fig. 1 & fig. 2).

2.4 A ¾ inch dia. Gate valve is to accommodate the pressurized hose attached to the bottom of the steel back plate. This valve is to provide a constant head of water in the stand pipe during the tests and also to serve as a drain after testing is completed (see fig. 1).

2.5 The stand pipe shall consist of the following:

2.5.1 Four – 5 foot sections of ¾ inch galvanized pipe.

2.5.2 Three – ¾ inch galvanized tees.

2.5.3 Three – ¾ inch galvanized plugs.

2.5.4 One – 8 inch funnel.

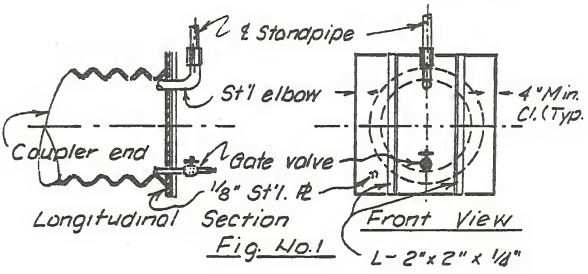
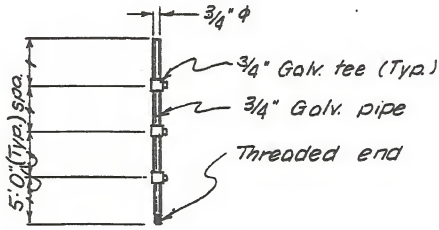


Fig. No.1



Standpipe Assembly
Fig. No.2

3 Procedure:

3.1 After attaching the bulkheads to the culvert test sections, the sections are coupled together, braced at the center to prevent sagging, and are filled to capacity with water.

3.2 The 20 foot stand pipe (fig. 2) is assembled and attached to the 3 inch elbow filler cap.

3.3 Water is introduced into the stand pipe from the bottom by means of the gate valve.

3.4 With water flowing continuously out of the first or bottom tee, and after waiting for a period of five minutes, a close examination is made of the test section for evidence of leakage.

3.5 The tee is plugged and the process repeated at each five foot increment until water flows out of the top of the stand pipe, the maximum twenty foot head.

3.6 A slight indication of "sweating" or "seepage ' at the test seams is permissible for irrigation pipe. Dripping or free flow of water is not acceptable. No sweating or other seepage for siphon pipe applications is permissible. If only the pipe seams are being tested but not the bands, some leakage at the bands may be allowed.

4 **Frequency of Test:**

4.1 Each diameter of pipe at least once a year at the discretion of the inspector.

METHODS OF SAMPLING AND TESTING
MT 421-04
METHOD OF SAMPLING CONSTRUCTION FABRIC

1 Scope:

1.1 This method covers the sampling of woven fabric, non-woven fabric and impermeable membranes.

2 Description:

2.1 Construction fabrics consist only of long chain polymeric filaments such as polypropylene, polyethylene, polyamide, polyester or polyvinylidene-chloride formed into a stable network to insure that the filaments or yarns maintain their relative position to each other.

2.1.1 *Impermeable membranes* - used as trench liners or pond liners are similarly manufactured but are also treated to resist water intrusion. Membranes may be formed in uniform sheets with closed cells or formed in treated layers, one layer being impermeable and the other for reinforcement.

3 Sample:

3.1 Prior to installation of the fabric the following requirements are required to insure proper selection of fabric for each type of application:

3.1.1 The contractor shall submit to the engineer two copies of a manufacturer's certificate of compliance signed by a legally authorized official of the manufacturer and notarized. The certification shall represent physical and chemical test results that were performed on a representative lot of material being used by the department.

3.1.2 In addition to certifications, a sample for Acceptance testing is required. A sample fabric-test check list is attached.

3.1.3 All sampling of construction fabrics or membranes will be done at the project and witnessed by the Engineer for each type of application, i.e., drainage (light, heavy), erosion control (CL I, CL II & III), separation/ stabilization (medium, high), sediment control, paving and geomembranes. Samples with certifications will be submitted to the Materials Bureau for testing.

3.1.4 The size of sample for each application will be a minimum 1.5 foot wide strip cut across the full roll taken from a wrap of fabric not exposed to sunlight or abrasion (see Note 1).

3.1.5 Frequency of sampling shall be one sample for every 10,000 square yards (8,000 m^2) of application.

3.1.5.1 Each new roll used will be checked for variance of lot number and then, if necessary, resampled and submitted to the Materials Bureau for testing. (See Note 2)

3.1.5.2 The direction of roll must be identified in felt marker on the sample.

Note 1 - The sample must be cut so that the cut edge is perpendicular to the roll (machine) direction. It is important to identify the roll direction on the sample, as the direction of failure in the fabric must be identified.

Note 2 - The sample shall be labeled with the manufacturer's lot number and identification of fabric type, grade or product name, date of sampling, project number and sample number. Also, during shipping and storing, the fabric must be protected from direct sunlight, ultra-violet radiation, temperatures greater than 60°C (140°F), mud, dirt or any other foreign debris.

4 Specifications:

4.1 For basis of acceptance and testing requirements refer to the Standard Specifications for Road and Bridge Construction. Since the Materials Bureau has a strict acceptance policy, proper sampling and correct submittal is essential.

METHODS OF SAMPLING AND TESTING
MT 422-04
METHOD OF TEST FOR SURFACE SMOOTHNESS AND PROFILE

1 **Scope:**

1.1 This method covers the testing of the finished flexible pavement surface for surface smoothness and surface profile. The surface smoothness is expressed in International Roughness Index (IRI) units of inches/mile or meters/kilometer. The surface profile is generated using Profile Index (PI) measurements and variations from this profile are expressed in inches/25 feet or millimeters/7.62 meters. This method is not intended to be used with rigid pavements or gravel surfacing.

2 **Referenced Documents:**

2.1 MDR 4080/4097 Mobile Data Recorder Operation Manual, International Cybernetics Corporation. All of the procedures for the actual operation of the road profilers are detailed in this user's manual.

3 **Apparatus:**

3.1 Class I laser road profiler – The manufacturer mounts the road profiling system on an automobile and performs the initial calibration of the system.

4 **Calibration:**

4.1 The manufacturer performs the initial calibration of the entire profiling system immediately after mounting the system on the vehicle.

4.2 Distance calibration (Conduct the distance calibration according to the MDR 4080/4097 Mobile Data Recorder Operation Manual from International Cybernetics Corporation.)

4.2.1 At screen 4-1, which is the Main Menu, highlight **Calibration** and hit enter. A pull-down menu will appear with **View** as the first choice. Highlight **View** and hit enter. This will bring up a screen that displays all the system configuration and calibration parameters from the sensor, accelerometer, and distance sections. Check these to make sure they are correct and then make a print out of the display. Do this by holding the **Shift** key and hitting the **Print Scrn** key with the printer on. Save this print out with the project test results as verification of the profiler's calibration prior to acceptance testing.

4.2.2 At the Main Menu, highlight **Calibration** and hit **Enter**. A pull-down menu will appear. Arrow down to **Distance** and hit **Enter**. The Distance window allows you to enter a Distance Calibration Factor (DCF) directly or establish a DCF by performing a calibration procedure. Each profiler must have a distance calibration performed at least once a week or after 2,000 miles of tire wear. The baseline distance for this calibration must be 5,280 feet (1,609 meters) or greater.

NOTE - The longer the pre-measured course used to calibrate the MDR system, the greater the accuracy of the data gathered.

4.2.3 The Distance menu has **DCF** and **Go** options. The DCF option includes the actual DCF entered in the MDR presently. This is a maximum of six (6) numbers followed by a letter. The number displayed is dependent on several factors that are established during the calibration procedure. The menu will also display one of the following three letters.

C Indicates that the entry was entered by completing the calibration process.

4 **Calibration:** (continued)

E Indicates that a DCF number has been entered into the system.

U Indicates that no entry of calibration has been performed by the operator.

4.2.4 Highlight the **DCF** option and hit **Enter** if entering an established DCF number. If a DCF number has not been established or a weekly calibration has not been performed, a distance calibration must be performed.

4.2.5 To perform a distance calibration procedure, position the test vehicle at the start position of the baseline course and select the **Go** option on the Distance menu and hit **Enter**.

4.2.6 This will activate a screen that will ask for the calibration distance of the baseline course. Enter the length of the course and hit **Enter**. This will bring up the Perform Distance Calibration Screen.

4.2.7 This distance calibration window allows the operator to store and average up to ten different DCF's. This is to reduce error in the DCF. To start a calibration procedure, press **F3**. This will cause another screen to appear in the distance calibration window that displays a pulse count giving the total number of pulses received from the distance sensor during the calibration test.

4.2.8 Hit **Enter** to start the calibration process and drive the length of the course.

4.2.9 When the test vehicle reaches the end of the measured course, press **BkSp** to stop the calibration process. If the run was normal and the number valid, it will be stored and displayed by the system. If the operator is not happy with the DCF, he may press the F8 key. This will delete the DCF that is highlighted. The UP and DOWN arrows can be used to highlight a selection for deletion.

4.2.10 If more DCF's are needed, press the F3 key. This makes the system ready for another run over the baseline course.

4.2.11 Repeat steps 4.2.8 and 4.2.9 as many times as necessary. The DCF average is updated constantly and displayed on the top line.

4.2.12 Once an ample number of DCF's have been recorded, use the arrow keys to move the highlighted area to either the (AV) average value or the one particular DCF that you would like to use. Once the desired value has been highlighted, hit the **F2** key to select the chosen value and the system will then display a verification line at the top of the screen.

4.2.13 Press the **Enter** key to store the highlighted DCF as the new system DCF. The system DCF is displayed on the lower left corner on the Distance Calibration screen.

4.2.13.1 If for any reason there was a mistake made that would affect multiple DCF's during calibration, press the **F9** key. Once the **F9** key is depressed, a verification line will appear at the top of the screen. The operator must then press the **Y** key for deletion. This will wipe out all DCF's and reset the distance calibration procedure.

4.2.14 To generate a hard copy of the Distance Calibration screen press the F7 key. A hard copy should be created and saved each time the calibration is performed.

4.2.15 When the calibration procedure is completed and the new DCF is saved, press the **F10** key. This will remove the system from the distance calibration collection mode.

*NOTE - Exiting does not automatically save the DCF average as the new value. The **F2** key should be used to save the new DCF in memory before exiting.*

4 **Calibration:** (continued)

4.3 Accelerometer calibration (Conduct the accelerometer calibration according to the MDR 4080/4097 Mobile Data Recorder Operation Manual from International Cybernetics Corporation)

4.3.1 The calibration of the accelerometer must be performed prior to beginning testing on each project.

4.3.2 At the **Calibration** menu, arrow down to **Accelerometer** and hit **Enter**.

4.3.3 A pulldown menu appears displaying the various accelerometer calibration parameters. These calibration parameters are:

ACcelerometer(s) = the number of configured accelerometers
ACF = Accelerometer Calibration Factor
FGF = Filter Gain Factor
HPF = Integrator Filter High Pass Frequency

4.3.4 The values displayed on the Accelerometer menu are generated by the MDR system when the Go function is activated, followed by the appropriate command(s). To generate the values select the **ACF** window and press **G** for Go and an accelerometer calibration screen will appear.

4.3.5 This screen displays the accelerometer calibration characteristics. Press **Enter** to start the accelerometer calibration.

4.3.6 Press **Bksp** to stop the calibration after a minimum of 2000 samples.

4.3.7 Press **Y** or **Enter** to accept the ACF and FGF values. Press N when you don't want to accept the values. When amplifier/filter is set for a gain of 2, the ACF values will be 1024 + 20, while the FGF will be between 1.97 and 2.00. If the amplifier/filter is set for a gain of 1, the ACF values will be 512 + 10 and the FGF will be between 1.01 and 99.

NOTE - The acceleration calibration should be done every day after the system has been warmed up for at least 15 minutes. The vehicle should be on a level section of pavement and anyone who is going to be involved with testing should be in his or her proper place in the vehicle during this calibration.

4.3.8 The values established by performing the sensor calibration procedure and displayed on this menu should be recorded for future reference.

4.4 Accuracy confirmation of laser height sensors (Check the accuracy of the laser height sensors according to section 6.3.3.9 of the MDR 4080/4097 Mobile Data Recorder Operation Manual from International Cybernetics Corporation).

4.4.1 The calibration check on the height sensors must be performed prior to beginning testing on each project.

4.4.2 The check must be performed on a level surface such as a garage floor.

4.4.3 Turn the system on and let it warm up for at least 10 minutes.

4.4.4 At the **Calibration** menu, arrow down to **Sensors** and hit **Enter**.

4.4.5 At the **Sensors** menu press **G** for Go. The Perform Sensor Calibration screen will appear.

4.4.6 Press **Enter** to start the sensor calibration.

4. Calibration: (continued)

4.4.7 Press **BkSp** to stop the calibration after a minimum of 1000 samples.

4.4.8 Press **N** or **Enter** since you do not want to accept the SCF(s).

4.4.8.1 The average height value displayed is in feet and depicts the distance from the laser camera standoff to the pavement/floor. A typical number will be 0.328 feet for a 200 mm laser and 0.210 feet for a 128 mm laser.

4.4.8.1.1 When changing a laser, installing, or reinstalling a laser, this should be checked first.

4.4.8.1.2 The value should be within + 0.03 feet of the required value on a straight floor with the operator(s) in the vehicle. The laser mounting plate should be adjusted to make the value within + 0.01 feet considering the levelness of the floor.

4.4.8.1.3 A calibration must be performed and the SCF values saved after the adjustments and check-out are accomplished.

4.4.8.2 After you have taken a base reading, place an object (i.e. metal calibration bar) of a known thickness under the laser camera.

4.4.8.3 The values on the screen should adjust exactly the thickness of the object. If they do not, contact the Pavement Management Section before you proceed.

4.4.8.4 The displayed numbers should be recorded. However, do NOT save the values.

4.5 Laser height sensor calibration (Calibrate the laser height sensors following the procedure outlined in section 6.3.3.10 of the MDR 4080/4097 Mobile Data Recorder Operation Manual from International Cybernetics Corporation).

4.5.1 Calibration of the height sensor system should be done at least once every three months or whenever a sensor is added, changed, or removed from a vehicle.

4.5.2 The check must be performed on a level surface such as a garage floor.

4.5.3 At the **Calibration** menu, arrow down to **Sensors** and hit **Enter**.

4.5.4 A pull down menu will appear.

4.5.4.1 Highlight the **Cal Temp** selection and hit **Enter**.

4.5.4.2 Enter the proper air temperature.

NOTE - This value must be entered prior to a sensor calibration. Do not change the Cal Temp if the sensor calibration factors (SCF) are not to be saved.

4.5.4.3 Arrow down to the **sEnsor config** selection and hit **Enter**.

4.5.4.4 The user can choose the sensor type by selecting the position number and toggling the enter key. The four selections are; None, Acoustic, Selcom 200 and Selcom 128. Check and make sure the correct sensors are shown.

NOTE - If the wrong sensor type is entered, the system will report invalid data. A sensor calibration must be performed after the sensor type is changed.

4. **Calibration:** (continued)

4.5.4.5 The remaining choices on this pulldown menu are as follows:

SCF - The SCF function is a system generated value. The value is used by the MDR system to mathematically compute the optimum levelness of the ultrasonic transducers mounted on the front bumper of the test vehicle.

Rate - The Rate function indicates the number of DMI pulses counted before a height measurement is sampled. It also indicates the maximum speed that the vehicle may travel without expecting errors due to too fast a sampling rate with ultrasonic sensors during testing. There are two rate categories: Laser & Acoustic. The rates categories enable the mix of lasers and ultrasonic sensors.

Low and High Values - The Low and High values are used to establish height values that the system should report errors in height measurement data from the ultrasonic transducers. This distance is calculated by the MDR system and is displayed for operator information as well as put into the data files. The error count can be monitored in both the calibration mode and the run mode.

Spacing - The Spacing function is used to enter the horizontal distance between the sensors. This allows proper rut depth calculations when five or more sensors are used (Note: MDT will not be using the rut depth functions in the testing for surface smoothness).

4.5.5 To perform the actual sensor calibration, select the **sensors** window and press **G** for Go. The Perform Sensor Calibration screen will appear.

4.5.5.1 This menu displays the number of sensors that are selected in the Run mode Options window. The sensor Calibration characteristics are:

Number of Samples - The number of readings taken by the sensors during the calibration procedure. A minimum of 1000 samples is recommended.

Sensor - The height sensor position number on the test vehicle.

Count - The count in microseconds the sensor required for the last height sample.

Height - The height of the last sample.

Avg. Height - Average height of all samples.

Gate/Zero - Number of hardware errors detected.

Low - Number of sensor readings that are below the Low limit.

High - Number of sensor readings that exceed the High Limit.

Dif - Number of samples where differences in successive samples are greater than 381mm.

Total - Total number of errors detected.

4.5.5.2 Press **Enter** to start the sensor calibration.

4.5.5.3 Press **BkSp** to stop the calibration after a minimum of 1000 samples.

4.5.5.4 Press **Y** only if this was an actual calibration and you want to accept the SCF(s). If it was not an actual calibration hit N or Enter.

4. Calibration: (continued)

NOTE - The values established during the calibration procedure are displayed on this menu. The values are also displayed on several other menus of the MDR system and are discussed to the appropriate depth for that application. It is recommended that the values established and displayed on this menu be recorded for future reference.

4.6 Statewide uniformity confirmation

4.6.1 A five mile calibration site will be set up in each district.

4.6.2 Take IRI measurements on the calibration site once a week or any time a problem is suspected.

4.6.2.1 The overall IRI value recorded on the entire five mile test site should not vary more than + 2 in/mile (0.032 m/km) from the average of the previous five tests conducted on the site.

4.6.2.2 Each of the 0.1 mile (0.3 km) sections should vary from the average of the previous five tests on that section by 10 in/mile (0.16 m/km) or less.

4.6.2.3 If a the calibration test does not pass the requirements of 4.6.2.1 and/or 4.6.2.2, rerun the calibration site making sure all of the proper procedures are followed.

4.6.2.4 A record should be kept of each time the calibration site is tested.

4.6.3 Measure the calibration site in the district, or in Helena, at the same time as one of the Pavement Management profilers and compare the results.

4.6.3.1 The side by side results of the two test runs should meet the same criteria established in 4.6.2.1 and 4.6.2.2.

4.6.3.2 The side by side tests should be conducted at least twice a year.

5 Project Testing:

5.1 Preparation of Surface:

5.1.1 The department will test the roadway only when it is free of moisture and any deleterious material that would not provide accurate test results. The contractor is responsible for all work to prepare the roadway for testing, such as, but not limited to sweeping.

5.1.2 Testing will not be conducted while it is raining or under other weather conditions determined inclement by the Engineering Project Manager.

5.2 Preliminary Project Preparation

5.2.1 Meet with the Engineering Project Manager (EPM) or one of his representatives and identify the Beginning-Of-Project (BOP), End-Of-Project (EOP), and all bridges that are not paved as part of the project. It will be necessary to conduct **two** runs, one for PI, and one for IRI. The order of testing is not important. A traffic cone must be set approx. 500 feet in advance of the begin point of testing and one approx. 500 feet beyond the end point of testing for both PI and IRI tests.

5.2.1.1 PI Test - Place event markers 25 feet (7.6 meters) prior to the BOP transverse paving joint, 25 feet (7.6 meters) after the EOP transverse paving joint. (See drawing, page 12)

5.2.1.2 IRI Test - Place event markers 150 feet (46 meters) after the BOP connection and 150 feet (46 meters) before the EOP connection. Place an orange traffic cone (non reflective) on edge of roadway at all bridge ends.

5. Project Testing: (continued)

5.2.2 Note any areas requiring additional traffic control to ensure a constant testing speed is maintained and work with the EPM to make arrangements for this traffic control.

5.2.3 Establish a beginning stationing and whether or not it is an English or metric project and use the measurement system consistent with the project stationing.

5.3 Profiler Set-up:

5.3.1 Turn on the main power switch for the MDR system.

5.3.2 Type M at the C: prompt and press Enter

5.3.3 As the MD090L program starts it will check for height sensors and accelerometers and attempt to operate them. If the hardware is not running properly or an invalid configuration is detected, the appropriate error message(s) will be displayed.

5.3.4 If everything is running properly the system will now display the Main Menu. This menu consists of the following choices; **Options**, **Parameters**, **Calibration**, **Run**, **File**, and **Quit**. Use the arrow keys to highlight the desired option and press Enter. This will bring up a pull down menu for the desired category.

5.3.4.1 The first menu to select is the **Options** menu. This is where the reference post display is selected. The options for this are feet, miles, meters, or kilometers.

5.3.4.2 Second, open the parameters window and put in the names of both the driver and the operator of the MDR system.

5.3.4.3 The next step is to go through all of the necessary system and sensor calibrations outlined in section "4. Calibration" of this test procedure.

5.3.4.4 Choose **Run** once the required calibration is completed. A fill in the blank menu with the following characteristics will open.

County - A 15 character alphanumeric field

Route - A 10 character alphanumeric field

Direction - N, S, E, W, A, D, F, R. Selects direction as North, South, East, West, Ascend, Descend, Forward, or Reverse and sets Asc/Dsc to + for N A F & E or – for S D R & W. Asc/Dsc can change the + or – as required also.

Beg Ref Point - Beginning point in meters, kilometers, feet, or miles. Entering a whole number implies feet or meters, while a decimal value implies miles or kilometers, as appropriate.

Asc/Dsc Ref Point - Change ref point to ascend or descend in value. Use after direction is selected to change sign.

Lane - A 10 character alphanumeric field.

Options - Allow data collection options to be changed.

Data Directory - File path for storing data files (**d:**\(four digit control number ex. 4582)\(lane designation ex. nb)\ (**iri** if collecting iri or **pi** if collecting pi) ex. d:\4582\nb\iri

5. **Project Testing:** (continued)

1 File Name - A 15 character alphanumeric field. Use **run1** for file name. If more than one run per iri/pi/lane is necessary then name subsequent files run2, run3, etc.

2 Ref - A 15 character alphanumeric field

3 Ref - A 15 character alphanumeric field

Weather - Sets of values describing weather information

NOTE - Some user codes selected in the Options Window will cause the above fields to have their names changed or will have the values in selected fields be used to name the data file. Use as appropriate for your established operations.

5.3.4.5 Enter all of the relevant information that is needed on the final report.

5.3.5 The system is now ready to begin testing. Select **Go** under the **Run** menu and the data collection screen will come up.

5.3.5.1 ***PI test*** - Bring vehicle up to speed and press the **F3** key to start the data collection process at the first cone approximately 500 feet in advance of the new pavement.

5.3.5.1.1 The profiler will automatically actuate an F9 function at the reflective tape that was placed 25 feet before the BOP and will automatically actuate an F8 function at the reflective tape that was placed 25 feet beyond the EOP.

5.3.5.1.2 Press the **F3** key at the cone that was placed approx. 500 feet beyond the test pavement to stop the data collection process.

5.3.5.1.3 The F10 key should be used to exit the data collection and save the data collected into a disk file. The screen will then show the name of the file including the path to which data will be saved.

NOTE - If the ESC key is hit, you will be given the option to save data. If you say "no", the data will be lost completely. This should only be done if the data is not to be saved on disk.

5.3.5.2 ***IRI test*** - Bring vehicle up to speed and press the **F3** key to start the data collection process at the first cone approximately 500 feet in advance of the new pavement.

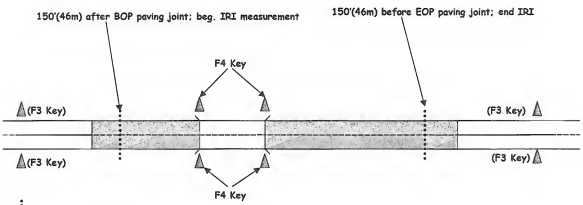
5.3.5.2.1 The profiler will automatically actuate an F9 function at the reflective tape that was placed 150 feet after the BOP joint and will automatically actuate an F8 function at the reflective tape that was placed 150 feet before the EOP joint. The operator will manually actuate an F4 function at cones placed on the bridge ends of all bridges that should be excluded according to the ride specification. The profiler will automatically omit IRI measurement 150 feet ahead and 150 after the F4 location.

5.3.5.2.2 Press the **F3** key at the cone that was placed approx. 500 feet beyond the test pavement to turn the roughness measurement off.

5.3.5.2.3 The F10 key should be used to exit the data collection and save the data collected into a disk file. The screen will then show the name of the file including the path to which data will be saved.

NOTE - If the ESC key is hit, you will be given the option to save data. If you say "no", the data will be lost completely. This should only be done if the data is not to be saved on disk.

IRI Measurement Layout (project)

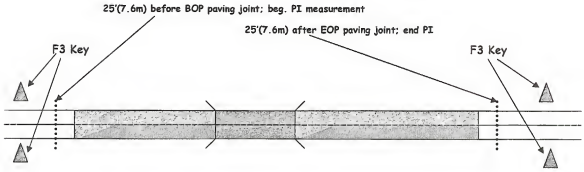


Event Markers (reflective tape on rdwy.) Equipment will automatically actuate F9 then F8 at tape.

Traffic Cones, Set approx 500 feet before and after paving joints and at all bridge ends on bridges that are excluded from ride spec.

Note: The F3 and F4 key are manually actuated by operator

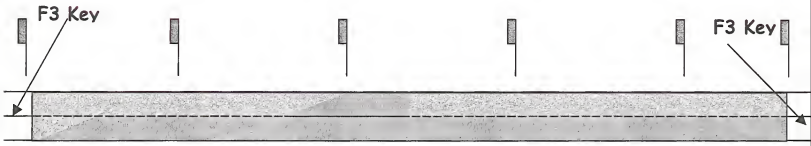
PI Measurement Layout (project)



Event Markers (reflective tape on rdwy.) Equipment will automatically actuate F9 then F8 at tape.

Traffic Cones, placed Approx. 500' before and after paving joint. Manually actuate F3 key here.

Five Mile Calibration Run Layout



Instructions:

1. Make sure vehicle is warmed up and static calibration performed
2. Go to Options screen, select Mile
3. Go to Run screen:
4. In Data Directory, type G:\ (this will default to the zip drive)
5. In Filename, type current date for file name (ex. aprl1400 cannot exceed 8 chars.)
6. Select Go
7. Bring vehicle up to speed and press the F3 key at the first milepost
8. Press the F3 key again at the last milepost
9. Press F10, then esc. Then press enter at filename box
10. Type Q then Y
11. At the C:\> prompt type G: (you will then be in the G: drive, be sure to have a disk in the zip
12. At the G:\> prompt type DIR to check for files
13. Type dist4IRI space filename space 1 then press return (ex. dist4IRI april400 1)

CURRENT DATE OF REVISION
MT-500 SECTION (INFORMATION)

Test Method No.	Title	Pages	Date of Publication or Revision
MT-501	Definitions	pp 1-7	April 1987
MT-502	Conversion Tables	pp 1	April 2000
MT-503	Samples and Certifications	pp 1	April 1979
MT-504	Vacant		
MT-505	Voids Table	pp 1	April 1970
MT-506	Moisture Correction for Concrete Mix Designs	pp 1	April 1996
MT-507	Vacant		
MT-508	Method of Figuring Yield of Concrete	pp 1-3	April 1979
MT-509	Vacant		
MT-510	Field Numbering Concrete Cylinders	pp 1-2	April 1995
MT-511	Terms Relating to Subgrade, Soil Aggregate and Fill Materials	pp 1-2	April 1968
MT-512	Numbering Subgrade Material, Surfacing Material, Bituminous Treated Material and Liquid Asphalt	pp 1	Aug. 2002
MT-513	A Guide for Laboratory Forms	pp 1-2	Aug. 2002

R177
METHODS OF SAMPLING AND TESTING
MT 501-04
DEFINITIONS

SOIL ENGINEERING TERMS:

Gradation – A term used to describe the range and the relative distribution of particle sizes in a material.

Well-graded soils – Those soils, which have a good representation of all particle sizes from the largest to the smallest but with a very small percentage of fines.

Poorly-graded soils – Those soils in which the range of particle sizes is very small or soils having a deficiency in some of the intermediate sizes or soils containing excessive fines.

Liquid Limit – The moisture content, which is the boundary between the liquid and plastic states for the minus No. 40 fraction of a soil. For laboratory purposes it may be defined as the moisture content at which that soil fraction will close a standard groove for a length of 1/2 inch when subjected to 25 blows in a liquid limit device.

Plastic Limit – The moisture content, which is the boundary between the plastic and semi-solid states for the minus No. 40 fraction of the soil. For laboratory purposes, it may be defined as the minimum moisture content at which the soil fraction can be rolled into a thread 1/8 inch in diameter without crumbling.

Plastic Index – The numerical difference between the moisture content of the Liquid Limit and the moisture content of the Plastic Limit.

Moisture Content – The weight of water in a given soil mass divided by the oven dry weight of the soil and is expressed in percent.

Optimum Moisture – The moisture content, which will permit maximum-dry-unit weight to be obtained for a given compactive effort.

Degradation Value – A specification set for each project using aggregate and is defined as a value from 100 to 0 indicating the quality of fines produced by self-abrasion of aggregate in the presence of water. (100 is superior and below 35 is poor).

Wear Value – A specification set for each project using aggregate and is defined as the percentage of dry weight lost during the abrasion of coarse aggregate in a Los Angeles Machine with an abrasive charge.

Dust Ratio – The ratio of the portion passing the 200 mesh sieve to the portion passing the 40-mesh sieve and shall be no greater than two-thirds.

Specific Gravity Terms:

Absolute – The ratio of the weight of a given volume of solids to the weight of an equal volume of water at a stated temperature.

Apparent – The ratio of the weight of a given volume of impermeable material (the solid matter including impermeable pores) to the weight of an equal volume of water.

Bulk – The ratio of the weight of a given volume of permeable material (including both permeable and impermeable voids) to the weight of an equal volume of water.

Specific Gravity Terms: (continued)

Permeability – A measure of the facility of a soil to transmit liquids, largely dependent upon grain size distribution.

"Rice" Gravity – Defined as the maximum specific gravity (absolute) of the Uncompacted bituminous mixture.

Highway terms:

Base – Foundation for pavement.

Base Course – A term used to include the layers of relatively high quality materials placed above the sub-grade as a stress distribution medium to insure that the stress induced in the sub-grade will not exceed its strength.

Binder Course – The course, in sheet asphalt and bituminous concrete pavements, placed between base and surface courses.

Bleeding – The upward migration of bituminous material resulting in a film of bitumen on the surface.

Blow-Up – Localized buckling or shattering of rigid pavement caused by excessive longitudinal pressure.

Construction Joint – The vertical or notched plane of separation in pavement.

Contraction Joint – A full depth or weakened plane type joint designed to establish the position of any crack caused by contraction while providing no space for expansion of the pavement beyond its original length.

Corrugations – The regular transverse undulations in a pavement surface consisting of alternate valleys and crests.

Cracks – The approximately vertical cleavage due to natural causes or traffic action.

Crazing – A pattern of cracking extending only through the surface layer, a result of more drying shrinkage in the surface than the interior of plastic concrete.

"D" Lines – Disintegration characterized by successive formation of a series of fine cracks at rather close intervals paralleling edges, joints and cracks and usually curving across slab corners, initial cracks forming very close to slab edges and additional cracks progressively developing, ordinarily filled with calcareous deposits.

Disintegration – Deterioration into small fragments from any cause.

Distortion – Any deviation of pavement surface from the original shape.

Expansion Joints – A joint permitting the pavement to expand in length.

Faulting – The differential vertical displacement of slabs adjacent to joints or cracks.

Flecking – The dislodgement of a thin film of mortar from the outermost portion of occasional coarse aggregate particles on concrete surfaces, generally attributable to lack of bond between mortar and aggregate.

Highway terms: (continued)

Flexible Base and Pavements – A bituminous pavement consisting of a well-graded aggregate combined with asphalt cement and with sufficiently low bending resistance to maintain intimate contact with the underlying structure and to distribute loads to the foundation by aggregate interlock, particle friction, or surface tension. Principle elements of flexible pavements are wearing surface, base, sub-base and sub-grades.

Frost Heave – The lifting and distortion of a surface due to internal action of frost resulting from subsurface ice formation; affects soil, rock, pavement, and other structures.

Joints – Constructed junctions between adjacent sections of pavement or between pavement and structures.

Leveling Course – A course of variable thickness constructed immediately on top of base material or existing pavement to remove large irregularities prior to super-imposed treatment or construction. (Binder course may function as leveling course and be called Binder course, Leveling course or Binder-Leveling course).

Longitudinal Joint – Either a full depth or weakened-plane type joint constructed parallel to or along the centerline to control longitudinal cracking.

Map Cracking – Disintegration in which cracking of the slab surface develops in a random pattern; may develop over the entire surface or localized areas.

Pitting – The displacement of aggregate particles from the pavement surface due to the action of traffic or disintegration, without major displacement of cementing material.

Plane of Failure – The depth at which the voids in the wheel path and/or between the wheel path are comparable to the voids in the passing lane.

Progressive Scale – Concrete disintegration that at first appears as surface scaling but gradually progresses deeper.

Pumping – Displacement and ejection of water and suspended fine particles at joints, cracks and edges.

Raveling – The progressive disintegration of aggregate particles, by dislodgement, from the surface downward or edges inward.

Resurfacing – Supplemental surface placed on existing pavement to improve surface conformation or increase strength.

Rigid base and Pavements – A term applied to that type of pavement that is constructed with Portland Cement Concrete. Those, which due to high bending resistance, distribute loads to foundations over comparatively large areas.

Rutting – The formation of longitudinal depressions by wheel tracking.

Scaling – The peeling away of the surface of Portland Cement Concrete.

Scratch or Wedge Course – A course, separate from the binder course, placed on the base to overcome deficiencies as lack of or too much crown, or to adjust grade or super-elevation.

Settlement – The reduction in elevation of short sections of pavement or structures.

Highway terms: (continued)

Shoving – The displacement of bituminous pavement due to the action of traffic, generally resulting in bulging of the surface.

Shoulder – A portion of the roadbed between the traffic lane and the top of the ditch in cuts and the top of the slope in embankments.

Spalling – The breaking or chipping of rigid pavement at joints, cracks or edges, usually resulting in fragments with feather edges.

Stripping – The separation of asphalt from aggregate particles due to the presence of moisture in asphalt pavements.

Sub-base – Specified or select material, of a planned thickness, placed as a foundation for pavement.

Subgrade – The material in cuts, fills and fill foundations immediately below the first layer of sub-bas, base ore pavement.

Subsealing or Undersealing – The placing of waterproof material under existing pavement to prevent the vertical flow of water or suspended solids that fill the voids under pavement.

Surface Course – The top course of a pavement providing a surface resistant to traffic abrasion or imparting structural value to pavement.

Surface Scale – A peeling away of the surface mortar of Portland Cement Concrete exposing sound concrete, even though the scale extends into the mortar surrounding coarse aggregate.

Surface Texture – The surface character of pavement that depends on size, shape, arrangement and distribution of aggregates and cement or binder.

Thrust – The pressure exerted by a rigid pavement against other pavements or structures.

Warping – The deviation of pavement surface from its original shape caused by temperature and moisture differentials within the slab.

Warping Joints – A joint permitting then warping of pavement slabs when moisture and temperature differentials occur in pavement, i.e., longitudinal or transverse joints with bonded steel or tie bars passing through them.

Concrete:

Anchorage – That portion of a reinforcing bar, and any attachment thereto, designed to resist pulling out or slipping of the bar when subjected to stress.

Bleeding – The natural separation of a liquid from a liquid-solid or semisolid mixture; for example, water from freshly poured concrete.

Consistency – The degree of solidity or fluidity of freshly mixed concrete and commonly described as slump.

Fineness Modulus – The fineness modulus (FM) is an index of the fineness of an aggregate – the higher the FM, the coarser the aggregate. FM is the summation of the cumulative percentages of the material retained on the standard sieves divided by 100.

Concrete: (continued)

Honeycomb – A surface or interior defect in a concrete mass characterized by the lack of mortar between the coarse aggregate particles.

Laitance – Weak material, consisting principally of lime, which is formed on the surface of concrete, especially when excess water is mixed with the cement.

Saturated Surface Dry – A term used to describe the condition of an aggregate in which the pores of all the particles are completely filled with water, but their surfaces are free from moisture.

Slump – A measure of concrete consistency.

Curing Period – A period provided to prevent the formation of surface cracks due to the rapid loss of water while the concrete is plastic and to ensure attainment of the specified strength.

Yield – The cubic feet of concrete produced per sack of cement.

Admixtures – Materials other than cement, aggregate and water in concrete used or entrain air, retard setting or accelerate setting.

Asphalt Terms:

Asphalt Cement – Fluxed or un-fluxed asphalt especially prepared for use in making bituminous pavements.

Batch – The quantity of mix discharged from the mixer in one complete operation of the plant before additional materials are introduced.

Bleeding – The presence of an excessive amount of asphalt on the surface due to either to an excessive amount of prime or tack coats or excessive asphalt in the mix.

C-Factor – Determined by the change in viscosity of asphalt cement during the mixing process relative to that during the Thin-Film Oven test and is used to determine whether incomplete combustion of or contamination by burner fuel is causing or could cause asphalt concrete pavement tenderness.

Cutback Asphalt – Asphalt cement that has been rendered liquid by fluxing with a petroleum distillate. (includes: RCs – Rapid Curing; MCs – Medium Curing; SCs – Slow Curing.)

Emulsion – An emulsion of asphalt cement and water with a small quantity of an emulsifying agent.

Prime Coat – The initial application of low viscosity liquid asphalt to an absorbent base prior to placing asphalt concrete.

Tack Coat – A thin layer of bitumen, road tar, or emulsion laid on a road to enhance adhesion of the course above it.

Volume Swell – The increase in volume of compacted aggregate, soil, sand, or a combination of aggregates passing the 10 mesh sieve (2.0 mm) and stabilized with bituminous material, when soaked in water for a standard length of time.

Immersion Compression – A method for measuring the loss of cohesion resulting from the action of water on compacted bituminous mixtures containing penetration graded asphalts.

Marshall Method of Asphalt Mix Design – A method that uses the measurement of resistance to plastic flow of cylindrical specimens of bituminous paving mixtures loaded on the lateral surface by means of the

Asphalt Mix Design Terms:

Marshall apparatus to achieve the following characteristics; sufficient asphalt, sufficient mix stability, sufficient voids and sufficient workability.

Marshall Stability – The stability measured during loading in the Marshall apparatus and is used to determine whether the compacted bituminous mixture will satisfy the demands of traffic without distortion or displacement.

Marshall Flow – The lateral deformation of the specimen at the point of maximum stability during loading in the Marshall apparatus, measured in hundredths of an inch and recorded as a whole number (0.15 inches becomes 15).

Asphalt Mix Design Terms: continued

Quality Assurance – Defined as a contractual method used to monitor the quality of material incorporated into Plant Mix Surfacing and Portland Cement Concrete Pavement, and in the case of Plant Mix Surfacing, the density of the finished pavement. This is achieved by random sampling and or testing of contractor produced materials that will be used to establish price adjustments on a statistical basis.

Anti-Rutting Specification – Defined as a series of specifications to reduce rutting. It requires a minimum of 70% mechanical fracture on at least one face of the 4 mesh fraction of material, revised aggregate gradation specification to conform to maximum density gradation curve. It allows a 1.05 pay factor as an incentive to stay closer to maximum density line and maintain greater uniformity. The temperature of the mix upon discharge from all mixers including drum dryers id specified in the mix design memorandum. Also, a Quality Assurance Plan is required.

Acceptance Samples and Tests – These are samples taken and tests made to ascertain on a day-to-day basis whether the quality of the materials being incorporated or proposed for incorporation into the construction conform to the plans and specifications.

Independent Assurance Samples and Tests – These are samples taken and tests made to provide an independent spot check of the adequacy and effectiveness of the results obtained in Acceptance sampling and testing and to supplement these test results. The samples are split in the field either into two or three portions that are tested by the field, district, or area, and the Materials Bureau in the case of a three-way split. These test results are used to compare testing procedures between the three laboratories.

Final Record Samples and Tests – These samples and tests are taken at random from completed construction work or completed portions thereof. They are to provide an independent spot-check of the adequacy and the effectiveness of the results obtained in Acceptance sampling and testing and to supplement theses test results.

Symbols:

The following are some of the more common symbols used in highway construction:

AASHTO - American Association of State Highway and Transportation Officials
AC - Asphalt Cement

ASTM - American Society for Testing Materials
BST - Bituminous Surface Treatment
BTB - Bituminous Treated Base
CAPAC - Corrugated Aluminum Pipe Arch Culvert
CAPC - Corrugated Aluminum Pipe Culvert
Symbols: continued:

CSPAC - Corrugated Steel Pipe Arch Culvert
CSPC - Corrugated Steel Pipe Culvert
CTB - Cement Treated Base
FHPM - Federal-aid Highway Program Manual
FM - Fineness Modulus
FR - Final Record
IA - Independent Assurance
LTB - Lime Treated Base
MT - Montana Test
PC - Portland Cement
PCCP - Portland Cement Concrete Pavement
PMB - Plant Mix Base
PMS - Plant Mix Surfacing
PSI - Pounds Per Square Inch
QA - Quality Assurance
PCPAC - Reinforced Concrete Pipe Arch Culvert
RCPC - Reinforced Concrete Pipe Culvert
RMS - Road Mix Surfacing
SC - Seal Coat
SG - Specific Gravity
SPPAC - Structural (Sectional) Plate Pipe Arch Culvert
SPPC - Structural (Sectional) Plate Pipe Culvert

METHOD OF SAMPLING AND TESTING
MT 502-04
CONVERSION TABLES

Water:

7.5 gal. water	=	1 cu. ft.
1 cu. ft. water	=	62.23 lbs.
3785 cc water	=	1 gal.
8.32 lbs. Water @ 25°c	=	1 gal.
231 cu. in. water	=	1 gal.
1728 cu. in. water	=	1 cu. ft.

Volume Measurements:

1 cu. in.	=	0.000579 cu. ft.
1 cu. ft.	=	1728 cu. in.
1 cu. yd.	=	27 cu. ft.
1 cu. meter	=	35.31445 cu. ft.
1 cu. centimeter	=	0.0000353 cu. ft.

Weight Measurements:

1 oz.	=	28.35 grams		
1 lb.	=	453.59 grams	=	0.454 kilograms
1 oz.	=	0.0625 lbs.		
1 lb.	=	16 oz.		
1 kilogram	=	2.2 lb.	=	1000 grams

Length Measurements:

1 in.	=	0.0833 ft.	=	2.54 cm.	Circle	=	3.1416 x R5
1 yd.	=	3 ft.	=	36 in.	1 sq. mile	=	640 acres
1 rod	=	16.5 ft.	=	198 in.	1 acre	=	43560 sq. ft.
1 chain	=	66 ft.	=	792 in.	1 sq. yd.	=	9 sq. ft.
1 mile	=	5280 ft.	=	1760 yd.	1 sq. yd.	=	1296 sq. in.
1 cm	=	0.032808 ft.	=	0.3937 in.	1 sq. ft.	=	144 sq. in.

Area:

Estimated Equivalents:

1 cu. ft. concrete	=	150 lbs.
1 cu. ft. clay, undisturbed	=	110 lbs. dry; 135 lbs. wet
1 cu. ft. sand	=	100 lbs. loose; 115 lbs. consolidated
1 cu. yd. compacted clay	=	3500 lbs. (wet weight)
1 cu.yd. compacted stabilized gravel	=	3800 lbs.

cu. yds. x 1.9 = tons compacted stabilized gravel
1 mile x 1 ft. x 1 in. compacted stabilized gravel = 30.8 tons

Miscellaneous:

Multiply	by	To obtain
ft. per second	0.68182	miles per hour
miles per hour	88	feet per min.
pounds of water per min.	0.016021	cu. ft. per min.
cu. ft. per min.	0.12468	gal. per second

http://www.hydrocut.com/Conversion/ConversionFactors.htm

METHODS OF SAMPLING AND TESTING
MT 503-04
SAMPLES AND CERTIFICATIONS
(Montana Method)

1 Scope:

1.1 This procedure is intended as a general guide to assist in determining whether material designated for use on a highway project should be sampled or should be accepted on certification.

2 Referenced Documents:

2.1 ***MT Manual:***
MT 601 Materials Sampling, Testing and Acceptance Guide

3 Samples and Certifications:

3.1 In general, every item used must be sampled and an acceptance received before it can be incorporated into the work unless acceptance can be made based on the manufacturer's certification , field tests, or field inspection reports.

3.2 All major items to be sampled and tested and most items that may be accepted on the manufacturer's certification or label are listed in alphabetical order in MT-601 with instructions for sampling, testing, and acceptance.

4 Small Quantities:

4.1 Projects requiring only small quantities of materials may not require sampling and testing of certain items such as surfacing aggregates for projects under 500 tons, plant mix aggregate for projects under 500 tons, etc. MT- 601 covers most of the commonly used items included in this small quantity category.

5 Optional Samples:

5.1 Should there be any question relative to the quality or validity of a material or should the Project Manager wish to obtain more samples than the minimum required, he has the option to submit a s many additional samples as may be necessary to insure that specification material is being used. All materials incorporated into the project, whether represented by actual samples or certification, are subject to final field inspection and acceptance by the project Manager.

6 Official Samples:

6.1 Samples of material to be incorporated into the work must be either sampled by, or the sampling must be witnessed by, a representative of the engineer in order to be considered official samples.

7 Report Form:

7.1 Most major materials to be tested have a report form designed for their exclusive use. It is of the utmost importance that these forms be completed as fully as possible.

7.2 All other materials not covered by a particular report form, whether represented by a sample or a certification, must be accompanied by a ***miscellaneous report form No. 45.*** It is equally important that this report be fully completed. This form should show the name of the product, quantity involved, name and address of the manufacturer and / or supplier, etc. In the case of an acceptance on the basis of a certification, a remark must be made that no sample is being submitted and the acceptance is being made on the basis of pre-test, manufacturer's certification or label, Division Laboratory report, etc.

MONTANA HIGHWAY DEPARTMENT
MATERIALS DIVISION
MT 505-04

VOIDS TABLE

Percent Voids $\frac{SG \times 6.7.355 - wt.}{SG \times 62.3555} \times 100$

Voids shown to the nearest one-tenth (1/10)

S.G.	2.55	2.26	2.57	2.58	2.59	2.60	2.61	2.62	2.63	2.64	2.65	2.66	2.67	2.68	2.69	2.70
Wt/Ft^3																
90	43.4	43.6	43.9	44.1	44.3	44.5	44.7	44.9	45.1	45.3	45.5	45.7	45.9	46.1	46.3	46.5
91	42.8	43.0	43.2	43.4	43.6	43.9	44.1	44.3	44.5	44.7	44.9	45.1	45.3	45.5	45.7	45.9
92	42.1	42.4	42.6	42.8	43.0	43.2	43.5	43.7	43.9	44.1	44.3	44.5	44.7	44.9	45.1	45.4
93	41.6	41.7	42.0	42.2	42.4	42.6	42.9	43.1	43.3	43.6	43.7	43.9	44.1	44.3	44.5	44.8
94	40.9	41.1	41.3	41.6	41.8	42.0	42.2	42.5	42.7	42.9	43.1	43.3	43.5	43.7	44.0	44.2
95	40.2	40.5	40.7	40.9	41.2	41.4	41.6	41.8	42.1	42.3	42.5	42.7	42.9	43.1	43.4	43.6
96	39.6	39.9	40.1	40.3	40.6	40.8	41.0	41.2	41.5	41.7	41.9	42.1	42.3	42.5	42.8	43.0
97	39.0	39.2	39.5	39.7	39.9	40.2	40.4	40.6	40.8	41.1	41.3	41.5	41.7	42.0	42.2	42.4
98	38.4	38.6	38.8	39.1	39.3	39.5	39.8	40.0	40.2	40.5	40.7	40.9	41.1	41.4	41.6	41.8
99	37.7	38.0	38.2	38.5	38.7	38.9	39.2	39.4	39.6	39.9	40.1	40.3	40.5	40.8	41.0	41.2
100	37.1	37.4	37.6	37.8	38.1	38.3	38.6	38.8	39.0	39.2	39.5	39.7	39.9	40.2	40.4	40.6
101	36.5	36.7	37.0	37.2	37.5	37.7	37.9	38.2	38.4	38.6	38.9	39.1	39.3	39.6	39.8	40.0
102	35.8	36.1	36.3	36.6	36.8	37.1	37.3	37.6	37.8	38.0	38.3	38.5	38.7	39.0	39.2	39.4
103	35.2	35.5	35.7	36.0	36.2	36.5	36.7	36.9	37.2	37.4	37.7	37.9	38.1	38.4	38.6	38.8
104	34.6	34.8	35.1	35.3	35.6	35.8	36.1	36.3	36.6	36.8	37.1	37.3	37.5	37.8	38.0	38.2
105	34.0	34.2	34.5	34.7	35.0	35.2	35.5	35.7	36.0	36.2	36.5	36.7	36.9	37.2	37.4	37.6
106	33.3	33.6	33.8	34.1	34.4	34.6	34.9	35.1	35.4	35.6	35.8	36.1	36.3	36.6	36.8	37.0
107	32.7	33.0	33.2	33.5	33.7	34.0	34.2	34.5	34.8	35.0	35.2	35.5	35.7	36.0	36.2	36.4
108	32.1	32.3	32.6	32.9	33.1	33.4	33.6	33.9	34.1	34.4	34.6	34.9	35.1	35.4	35.6	35.8
109	31.4	31.7	32.0	32.2	32.6	32.8	33.0	33.3	33.5	33.8	34.0	34.3	34.5	34.8	35.0	35.3
110	30.8	31.1	31.4	31.6	31.9	32.1	32.4	32.7	32.9	33.2	33.4	33.7	33.9	34.2	34.4	34.7
111	30.2	30.5	30.7	31.0	31.3	31.5	31.8	32.1	32.3	32.6	32.8	33.1	33.3	33.6	33.8	34.1
112	29.6	29.8	30.1	30.4	30.6	30.9	31.2	31.4	31.7	32.0	32.2	32.5	32.7	33.0	33.2	33.5

$$Percent\ Solids = \frac{Wt/Ft3}{SGx62.4} x100$$

METHODS OF SAMPLING AND TESTING
MT 506-04
MOISTURE CORRECTION FOR CONCRETE MIX DESIGNS
(Montana Method)

1 Scope:

1.1 This method describes the procedure for making a correction in the moisture requirement of a concrete mix, due to absorbed moisture. Concrete mix designs furnished by the Materials Bureau are based on saturated surface dry aggregate and the moisture correction must be made when concrete is produced. Moisture may be figured on a one sack basis or on a one cubic meter (one cubic yard) basis. A typical Class "A" mix for one sack of cement would be shown as: 94 - 213 - 190 - 190.

2 Moisture Requirement:

2.1 The example mix makes no mention of water as it is controlled by slump requirements, but for the purpose of mix designs it is assumed to be 22.7 liters (6 gallons) per sack of cement. This 22.7 liters (6 gallons) is not a specified amount to be used, and in fact, a lesser amount will most generally obtain the required slump. 22.7 liters (6 gallons) per sack is the maximum net amount of water which may be used under Montana Specifications, and includes free water in excess of water absorbed by the aggregates, additives, air entraining agents, etc.

2.2 It is impossible for the Materials Bureau to know in advance what the moisture condition of the aggregate stockpiles will be when concrete is ultimately produced, so the following procedure is to be observed.

3 Absorption of Fine Aggregate:

3.1 Fine aggregate will always require an adjustment for the moisture content. A moisture content will seldom be less than 3% or more than 7%. The moisture correction is made by multiplying the aggregate weight shown by 100 plus the percentage of moisture in the material. If a moisture determination shows that the sand has 5% total moisture, multiply the sand weight shown by 105%. This would make the new sand weight about 102 Kg (224 pounds), which would total about 5 Kg (11 pounds) of water (free and absorbed) or approximately 5.0 liters (1-1/3 gallons) per sack.

3.2 If the fine aggregate has an absorption of 1.0%, the amount of water that can be counted as free water (mix water) would be computed as follows:

3.2.1 5.0% (total moisture) minus 1.0% (absorption) equals 4.0% free water.

3.2.2 96.6 Kg (213 lbs.) x .04 (4% free water) equals approximately 3.9 Kg (8.5 lbs.) free water.

3.2.3 Therefore, only 3.9 Kg (8.5 lbs.) of water would be counted as mix water.

4 Absorption of Coarse Aggregate:

4.1 Medium and coarse aggregate are open-graded and free draining and will not usually require a correction for moisture unless they are being used directly from a washing plant or are being heated with live steam.

4.2 If a correction is deemed necessary, the procedure shown for fine aggregate will be followed.

5 Corrected Mix:

5.1 The corrected mix would be: 94 - 224 - 190 - 190.

METHOD OF SAMPLING AND TESTING
MT 508-04
METHOD FOR FIGURING YIELD OF CONCRETE
(*Montana Method*)

1 Scope:

1.1 This method is intended to be used to figure the yield of a mix design for Portland cement concrete, either by a one sack mix or a one cubic foot mix, when critical values of the various ingredients are known.

1.2 An example of a basic mix design, as furnished by the Materials Bureau might be:

Class "A" = 94 – 213-190-190

1.3 Cubic yard quantities are obtained by multiplying the individual weights, as shown, by the number of sacks of cement required for the class of concrete being used.

2 Requested Number of Sacks of Cement

2.1 The number of sacks of cement required for various classes of concrete are as follows:

Plain	***With Additive***
Class A & D = 5.5	**Class AA & DA = 5.0**
Class AD & DD = 6.5	**Class ADA & DDA = 5.9**
Class AP & DP = 6.0	**Class APA & DPA = 5.5**
Class AS & DS = 7.0	**Class Pre. Min = 6.5**
Class AC & DC = 4.5	

3 Water:

3.1 Water content is not stated as it is controlled by slump requirements but for mix design purpose it is always figured as 6 gallons per sack, total water, in the mix. This figure includes free water added, moisture in material, additives, air entraining agents, etc.

4 Total Paste:

4.1 Total paste for a one sack mix need not be figured as it is always the same, 1.28 cubic feet, arrived at as follows: 6 gals. Water divided by 7.5 (gallons of water per cubic foot) equals .80 cubic foot. One bag of cement, 94 pounds, divided by 196.6 pounds (solid weight of cement) = .48 cubic foot. Then .80 + .48 =1.28 cubic feet. This figure multiplied by sacks of cement used gives the total paste in a cubic yard of concrete.

5 Fine Aggregate:

5.1 Volume of fine aggregate is determined by dividing the weight of sand used in the mix by the solid weight of that sand which is the specific gravity of the sand multiplied by the weight of water per cubic foot (62.4). Example:

Specific gravity of sand 2.61 x 62.4 =162.9 solid weight of sand. 213 pounds sand divided by 162.9 = 1.3075 cubic feet of sand per sack of cement.

1.3075 times the total number of sacks of cement used will give the volume of sand in one cubic yard of concrete.

6 Medium and Coarse Aggregate:

6.1 The volume of the medium and coarse aggregates are figured in the same manner as the sand or they may be combined and figured as total coarse aggregate which is usually done. The total coarse aggregate in the mix above is 380 pounds. The specific gravity of the medium aggregate is 2.61 and the specific gravity of the coarse aggregate. 380 pounds of aggregate divided by 163.5 = 2.324 cubic feet of rock per sack of cement.

7 Yield:

7.1 Yield may be figured on a one sack basis or on a one cubic yard basis, whichever is most convenient. Yield is the sum of the solid volumes of all of the ingredients, which go to make a yard of concrete, including air.

7.1.1 One sack mix:

Paste - 6 gallons water, 1 sack cement = 1.28 cubic feet

Sand - 213 pounds divided by 162.9 = 1.3075 cubic feet

Rock - 380 pounds divided by 163.5 = 2.3240 cubic feet

Total volume for each sack of cement = 4.9115 cubic feet

Total Volume per cubic yard = 4.9115 x 5.5 = 27.0132 cubic feet.

7.1.2 One Cubic Yard Mix:

Paste - 5.5 x 1.28 = 7.04 cu. ft

Sand - 5.5 x 213 = 1172 lbs. Sand divided by 162.9 = 7.1945 cu ft.

Rock - 5.5 x 380 = 2090 lbs. Coarse divided by 163.5 = 12.7828 cu. Ft.

Total volume per cubic yard = 27.0173 cu. Ft.

8 Data for Figuring Concrete Yield:

The following data is recorded as a convenient reference:

8.1 Cement:

8.1.1 Weight per sack = 94 lbs

8.1.2 Absolute volume per sack = .48 cu ft

8.1.3 Specific gravity = 3.15

8.2 Water:

8.2.1 Weight per gallon = 8.33 lbs.

8.2.2 Weight per cu. Ft. = 62.4 lbs

8.2.3 Gal. Per cu ft. = 7.5

8.4 Volume of varying Amounts of Water in Cubic Feet:

8.4.1 1 gal = .1334 5 gals = .667 5.5 gals = .734 6.0 gals.= .80

9 Volume of Varying Amounts of Water Plus 1 Sack of Cement in Cubic Feet:

9.1 5.0 gal. + 94 cement = 1.15

9.2 5.5 gal. + 94 cement = 1.21

9.3 6.0 gal. = 94 cement = 1.28

10 Weight of Materials Divided by Specific Gravity x Weight of Water = Volume of Materials:

$$\frac{150}{2.65x62.4} = \frac{150}{165.4} = .90711 cu.ft.$$

11 Specific Gravity x Weight of Water x Volume of Material = Weight of Material:

2.65 x 62.4 = 165.4 x .90711 = 150 pounds.

12 Percent Voids:

$$\frac{\text{S. G. x 62.355} - \text{Wt.}}{\text{S. G. x 62.355}} \times 100$$

2.65 x 62.355 = 165.24 – 105 = 60.24 divided by 165.24 = 36.46 %

13 Solid Weights of Material for Various Specific Gravities:

S. G.	Solid WT.	S.G.	Solid WT.	S.G.	Solid WT.	S.G.	Solid WT
2.50 =	156.0	2.58 =	161.0	2.66 =	166.0	2.74 =	171.0
2.51 =	156.6	2.59 =	161.6	2.67 =	166.6	2.75 =	171.6
2.52 =	157.2	2.60 =	162.2	2.68 =	167.2	2.76 =	172.2
2.53 =	157.9	2.61 =	162.9	2.69 =	167.9	2.77 =	172.8
2.54 =	158.5	2.62 =	163.5	2.70 =	163.5	2.70 =	173.5
2.55 =	159.1	2.63 =	164.1	2.71 =	169.1	2.79 =	174.1
2.56 =	159.7	2.64 =	164.7	2.72 =	169.7	2.72 =	174.7
2.57 =	160.4	2.65 =	165.4	2.73 =	170.4	2.73 =	196.6

METHODS OF SAMPLING AND TESTING
MT 510-04
FIELD NUMBERING CONCRETE CYLINDERS
(Montana Method)

1 Scope:

1.1 The procedure outlined in this method has been adopted in order to establish a uniform, statewide numbering system for concrete test specimens.

2 Procedure:

2.1 Each class of concrete for the entire project shall have its own set of consecutive specimen numbers, starting with number "1" and continuing to the completion of the project. If the supplier of concrete is changed, a new set of consecutive specimen numbers will have to be used, representing the new source of supply.

2.1.1 The consecutive numbers will constitute the first part of the complete specimen number.

2.1.2 The next part of the specimen number will be the letters which designate the class of concrete being represented by the test specimen, i.e., 1A, 1AA, 1DD, 1DDA, etc.

2.1.3 The third part of the specimen number will be the stationing of the structure on which the pour was made.

2.1.4 The letter appearing last in the specimen number will designate the lane in which the structure is being built, when applicable.

3 Example:

3.1 An example of the numbering system might be "1AD1325E," meaning the first Class "AD" concrete cylinder made for the eastbound structure at Station 1325+10.35. The first and second part of the specimen number, as defined by paragraphs 2.1.1 and 2.1.2 will be consecutive throughout the project but the third and fourth part of the number, as defined by paragraphs 2.1.3 and 2.1.4, will change to identify the structure or structures involved.

4 Running Average of Strength:

4.1 The Materials Bureau will continue to keep a running average of the strength of each class of concrete on the project. The average will be for the entire project and not for individual structures. These averages will be reported to the Construction Bureau and the Division in which the project is located.

5 Split Loads:

5.1 On multiple structure jobs where one load of concrete is split and placed on more than one structure on the project, one set of test specimens will suffice, providing the split load of concrete is not altered in any way such as delaying successive pours, introducing additional water into the mix, etc.

6 Marking Sides of Cylinder:

6.1 All identifying markings on concrete cylinders shall be placed on the sides of the cylinder instead of, or in addition to, markings being placed on the ends. In addition to the specimen numbers described in paragraph 2 and 3, it is important to place the Project Number on the side of the cylinder. Several sets of cylinders may be received in the Materials Bureau at the same time bearing identical specimen numbers but representing different projects which prevents the specimens from being positively identified.

6 Marking Sides of Cylinder:

6.2 Concrete cylinders, upon arriving at the Materials Bureau, are immediately capped on both ends with a sulphur compound before being placed in the moist room to await the proper breaking date. If the field personnel place their identifying numbers on the end of the cylinders only, it is necessary for the Materials Bureau to transfer the identifying numbers to the side of the cylinder before it is capped, as the original information will be covered by the caps. Each time it is necessary to transfer identifying markings, the chances for errors increase.

METHODS OF SAMPLING AND TESTING
MT 511-04
TERM RELATING TO SUBGRADE, SOIL AGGREGATE AND FILL MATERIALS

1 Scope:

1.1 These definitions cover terms used in descriptions and specifications of materials occurring as or employed in the construction of sub-grades, soil-aggregate base and surface courses and fills.

2 Definitions of Rock and Soil:

2.1 ***Rock*** - Natural solid mineral matter occurring in large masses of fragments.

2.2 ***Soil*** - Sediment or other unconsolidated accumulation of solid particles produced by the physical and chemical disintegration of rocks and which may or may not contain organic matter.

2.3 ***Broken Rock*** - Angular fragments of rock which will be retained on a 3-inch sieve.

2.4 ***Boulders*** - Rounded fragments of rock, which will be retained on a 3-inch sieve.

3 Definitions of Soil- Aggregate and its Components

3.1 ***Soil – Aggregate (Dense- Grade Aggregate)*** - Natural or prepared mixtures consisting predominately of stone, gravel, or sand and containing silt-clay (minus No. 200 material) .

3.2 ***Stone*** - Crushed or naturally angular particles or rock which will pass a 3- inch sieve and be retained on a No. 10 sieve.

3.2.1 ***Coarse Stone*** - Stone passing the 3-inch sieve and retaining on the 1-inch sieve.

3.2.2 ***Medium Stone*** - Stone passing the 1-inch sieve and retaining on the 3/8-inch sieve.

3.2.3 ***Fine Stone*** - Stone passing the 3/8-inch sieve and retaining on the No. 10 sieve.

3.3 ***Gravel*** - Rounded particles of rock, which will pass a 3-inch sieve and be retained on a No. 10 sieve.

3.3.1 ***Coarse Gravel*** - Gravel passing the 3-inch sieve and retaining on the 1 –inch sieve.

3.3.2 ***Medium Gravel*** - Gravel passing the 1-inch sieve and retaining on the 3/8-inch sieve.

3.3.3 ***Fine Gravel*** - Gravel passing the 3/8-inch sieve and retained on the No. 10 sieve.

3.4 ***Sand*** - Granular material resulting from the disintegration, grinding, or crushing of rock and which will pass the No. 10 sieve and be retained on the 200 sieve.

3.4.1 ***Coarse Sand*** - Sand passing the No. 10 sieve and retaining on the No. 40 sieve.

3.4.2 ***Fine Sand*** - Sand passing the No. 40 sieve and retaining on the No. 200 sieve.

3.5 ***Silt-Clay (minus No. 200)*** - Fine soil particles which will pass the No. 200 sieve.

3.5.1 ***Silt Fraction*** - Material passing the No. 200 sieve. and larger than .005 mm.

3 Definitions of Soil- Aggregate and its Components:

3.5.2 ***Clay Fraction*** **-** Materials smaller than .005 mm.

3.6 ***Colloids*** **-** Materials smaller than .001 mm.

4 Definitions of Pavement Substructure Components:

4.1 ***Embankment Foundation*** **-** The material on which an embankment is placed.

4.2 ***Embankment (Fill)*** **-** A raised structure of soil, soil-aggregate, or rock.

4.3 ***Sub-grade (Basement Soil)*** **-** The prepared and compacted soil immediately below the pavement system and extending to such depth as will affect the structural system.

4.4 ***Sub-base*** **-** The layer used in pavement system between the sub-grade and the base course.

4.5 ***Base*** **-** The layer used in a pavement system to reinforce and protect the sub-grade or sub-base.

METHODS OF SAMPLING AND TESTING
MT 512-04
METHOD OF NUMBERING SUBGRADE MATERIAL, SURFACING MATERIAL, BITUMINOUS TREATED MATERIAL AND LIQUID ASPHALT
(Montana Method)

1 Scope:

1.1 This method is intended to standardize the procedure in assigning field numbers to subgrade, surfacing, bituminous treated material and liquid asphalt.

2 Field Numbering Procedure:

2.1 Sample numbers shall run consecutively throughout the project for each type and size of material. This must be repeated for each new source of material used on the project. Only one set of consecutive numbers is needed for contracts which involve two or more projects. All projects shall be listed, however, and the project for which the material is designated shall be indicated with a check mark.

3 Sub-grade Material:

3.1 In the case of sub-grade, each type of material would mean original ground, embankment, pipe bedding, ramp, etc. Numbering shall be as outlined in paragraph 2.

4 Surfacing Material (Crushed Top Surfacing, Crushed Base Course, etc.):

4.1 Samples shall be numbered in accordance with paragraph 2.

5 Plant Mix Surfacing, Plant Mix Base, Road Mix Surfacing, Bituminous Surface Treatment and Bituminous Treated Base:

5.1 In addition to samples of surfacing aggregates, samples of bituminous mixtures, as prepared for use in paving, shall be numbered as outlined in paragraph 2.

6 Liquid Asphalt:

6.1 Samples shall be numbered in accordance with paragraph 2. When switching to a liquid asphalt produced by a different company or to a different grade of liquid asphalt, the numerical sequence must return to number one. Refer to MT 601 for sample size and frequency of sampling.

6.2 When sampling liquid asphalt, sample numbers and lot numbers will run consecutively. If the manufacturer changes and the grade remains the same, the sample numbers will start over but the lot numbers will continue. If the grade of asphalt changes, the sample number and lot number will both start over.

Example 1:

Manufacturer	Grade		
MRC	PG 64-22	Sample No. 1 – 24	Lot No. 1 – 4
EXXON	PG 64-22	Sample No. 1 – 12	Lot No. 5 – 6
MRC	PG 64-28	Sample No. 1 – 18	Lot No. 1 – 3
MRC	PG 64-22	Sample No. 25 – 37	Lot NO. 7 - 8

METHODS OF SAMPLING AND TESTING
MT 513-04
A GUIDE TO LABORATORY FORMS
(Montana Form Nos.)

1 **Scope:**

1.1 This is a guide for the selection of the proper laboratory form when submitting samples, inspection reports, or certifications to the Materials Bureau.

2 **General:**

2.1 The following listing is given in two parts. Part I is used when submitting materials for testing. Part II tells which forms to use when submitting inspection reports or certifications for various types of materials. Each of these parts is further broken down into different classes of material (aggregate, asphalt, steel, etc.). Following each individual item is the number of the laboratory form to be used.

PART I

FORMS TO ACCOMPANY SAMPLES

Soil and Aggregates

Bedding Material - MBA 123
Blending Sand - MBA 123
Blotter Material - MBA 123
Binder - MBA 123
Borrow - MBA 123
Concrete Aggregate - MBA 124A
Crushed Base Course - MBA 123
Crushed Cover Aggregate - MBA 123
Crushed Top Surfacing - MBA 123
Cushion - MBA 123
Filter Material - MBA 123
Mineral Filler - MBA 123
Plant Mix Base Course - MBA 123
Plant Mix Surfacing - MBA 123
Proposed Surfacing - MBA 123
Proposed Concrete – MBA 124A
Sand Surfacing - MBA 123
Selected Surfacing - MBA 123
Soil and Water for Corrosion - 45
Soil for "R" Value - MBA 123
Topsoil - MBA 123

Asphalt

All asphaltic materials will be submitted on the following laboratory forms;
QA projects - CB-57
Non QA projects and maintenance - 10I-C

Steel Products

Reinforcing Bars - 45
Pre-stress Strand - 45
Wire Mesh - 45
Steel Pipe - 45

Miscellaneous Materials

Bark - MBA 123
Canvas Shims - 45
Cement - 55
Conduit - 45
Delineators - 45
Electrical Wire - 45
Expansion Joint Filler - 45
Fencing Items - 45
Glass Beads - 45
Mulch - 45
Paint - 45
Peat Moss - 45
Plastic Pipe - 45
Protective Coating - 45
Riprap - 45
Seed - 45
Signing Material - 45
U-posts - 45
Wood Cores - 45
Wood Preservatives - 45
Wood Products - 45

Bituminous Mixtures

Plant Mix Material for Extraction - 45
Plant Mix Material for Monitoring - 45
Plant Mix Pavement - 45

Concrete Samples

Concrete Cores - 45
Concrete Cylinders - 93
Concrete Cylinders (AR) - 77
Concrete Flexural Beams - 93

PART II

FORMS FOR INSPECTION AND CERTIFICATION

Certifications

Contractor's Certification of Compliance: Non-Structural Steel & Iron Items – Form 406
Contractor's Certification of Compliance: Miscellaneous Items – Form 407
All certifications of materials should be accompanied by Lab. Form No. 46

Inspection Reports

Corrugated Metal Pipe Culvert and Misc. Culvert Items - 102
Field Nuclear Density Tests - MBF 1000A
Pre-cast Concrete Items (Culverts, Barrier Rail, etc.) - 19A
Pre-stress Beam Inspection Report - 48
Pre-stress Beam Pre-tensioning Record - BR-12
Steel and Misc. Structural Materials
1) Fabrication Inspection - MB-2
2) Field Inspection - MBF 46
Welding Inspection
1) Pre-fabrication Welding - WI-1
2) Fabrication Welding - WI-2
3) Final Welding - WI-3
4) Miscellaneous Welding - WI-4
Wood Products - 45

CURRENT DATE OF REVISION
MT-600 SECTION (FIELD SAMPLING PROCEDURE)

Test Method No.	Title	Pages	Date of Publication or Revision
MT-601	Materials Sampling, Testing and Acceptance Guide Index (English Version)	pp 5-34	Aug. 2002
MT-601	Materials Sampling, Testing and Acceptance Guide Index (Metric Version)	pp 5-37	Aug. 2002
MT-602	Independent Assurance and Final Record Sampling	pp 1-5	April 1997

METHODS OF SAMPLING AND TESTING
MT 601-04
MATERIALS SAMPLING, TESTING AND ACCEPTANCE GUIDE - INDEX
ENGLISH VERSION

1 Scope:

1.1 This procedure is intended as a general guide to assist in determining the basis of sampling, testing, inspection and acceptance of various materials and products commonly used on our highway projects.

2 General:

2.1 Listed in MT-601, Sections I and II, are various materials and products, the basis of acceptance for which may vary depending on the specifications, procedures or circumstances relating to these items.

3 Samples and Certification, MT-601, Section I:

3.1 In general, the department's responsibility is to assure that the material is sampled at the appropriate interval and the contractor is responsible for taking a representative sample.

3.2 Material certifications from manufacturers or suppliers are to meet MDT specifications (refer to subsection 106.03, Certification of Compliance, 1995 Standard Specifications for Road and Bridge Construction). The certification must be provided by the prime contractor, be signed by a manufacturers authorized representative, clearly identifying each lot of certified material or assemblies delivered to the work, and be submitted from the field to the Materials Bureau with a properly filled out form 46, 406 or 407. The form must be signed by the person making the acceptance and be submitted through the Project Manager. The contractor should be aware that without proper certification, one or the other of the following conditions will affect final acceptance:

3.2.1 The Project Manager can allow the materials to be incorporated into the work; however, he will not pay for the material until certification is made available. If the certification indicates the material does not meet MDT specifications, he can have the material removed at the contractor's expense, or accept it at a reduced price.

3.2.2 The Project Manager will not allow the material to be incorporated into the work.

3.3 In general, unless acceptance can be made on the manufacturer's certification, outside testing agency or on field inspection reports, every item used must be sampled and tested with a statement of laboratory acceptance received before it can be incorporated into the work.

3.4 Other than proven trade name products which are discussed below in article 4, all major items to be sampled and tested, and all items that may be accepted on the manufacturer's certification or label are listed in alphabetical order with instructions for sampling, testing, and acceptance in MT-601, Section I. Whenever a conflict exists between a particular test method and MT-601, MT-601 will govern.

3.5 Acceptance of an established product may be made by the field, based on the manufacturer's certification and previous satisfactory field performance. Random samples will be taken by the field and tested by the Materials Bureau at least once a construction season.

4 Trade Name Products, MT-601, Section II:

4.1 All miscellaneous trade name products listed in Section II of MT-601 can be accepted in the field based on manufacturer's certification as long as the certification complies with subsection 106.03 (Certification of Compliance, 1995 Standard Specifications for Road and Bridge Construction). Products in Section II of MT-601 have been pre-qualified by the Materials Bureau and have proven to be acceptable when used and applied in accordance with the manufacturer's recommendations. They are acceptable for use without Materials Bureau approval, but cannot be used as a substitute for another product, grade, type, or class without prior written authorization by the Materials Bureau. To assure specification compliance, submit check samples to the Materials Bureau periodically for testing. Visual checks should also be made to verify the condition of the material.

4.2 In order to assure adherence to specifications, check samples should be submitted to the Materials Bureau periodically for testing. Visual checks should also be made to verify the condition of the material prior to use.

5 Inspected Items (Outside Testing Agency or MDT Laboratory)

5.1 Inspect all fabricated items during fabrication. Deliver this material to the project with permanent marks, identifying that it has been inspected, such as a metal tag (wood products), or a circle M stamp (RCP or CSP pipe, steel items, miscellaneous concrete products and signs). See attached for "Certification of Materials."

5.2 When properly marked materials are delivered to the project, they must be accompanied by a certification of materials report or a mill report submitted from the plant or point of manufacture, be completely filled out and signed by an authorized representative of the supplier or the designated inspection agency. A more detailed report will follow from the inspection agency including mill tests, material certification and the origin of manufacture for steel products.

5.3 Properly marked materials delivered to the project without a certification of materials or mill reports can be incorporated into the project at the Project Manager's discretion, but payment for the materials will be withheld until the reports are provided. It is the prime contractor's responsibility to ensure that proper reports are delivered to the Project Manager.

6 Small Quantity Items:

6.1 Projects requiring only small quantities of materials may not require standard acceptance sampling and testing. Items such as Grade C Plant Mix under 500 tons, paint under 25 gallons and minor quantities of concrete are examples. When items are designated as small quantities by the Project Manager, their acceptance will be based upon proper documentation, such as concrete mix design checks, air and slump test results, aggregate gradation results, etc. The Project Manager will notify the Helena and District Labs, in writing, whenever items are accepted on this basis.

7 Optional Samples:

7.1 All materials incorporated into the project, whether represented by actual samples or by certification, are subject to final field inspection and acceptance by the Project Manager. He has the option to obtain more than the required minimum number of samples and to submit as many additional samples as he deems necessary to insure conformance to specifications.

8 Samples:

8.1 Samples of material to be incorporated into the work must be sampled by the contractor and witnessed by an MDT representative in order to be classified as **official** samples.

8 Samples: (continued)

8.2 *Acceptance Samples* - Department personnel or an authorized representative will witness samples taken by the contractor.

8.3 *Quality Assurance* – Perform sampling for QA according to Montana Standard Specifications for Road and Bridge Construction for the item to be sampled. Department personnel or an authorized representative will witness samples taken by the contractor.

8.4 *Independent Assurance (IA)* - The Department requires that all sampling and testing for Independent Assurance purposes be accomplished by Department personnel or authorized representatives. IA samples must be taken under the direct supervision of the Materials Supervisor or his authorized representative and must not be scheduled on such an inflexible and regular routine that its frequency can be predicted, but sufficient samples must be submitted to satisfy the frequency intended.

8.5 *Final Record (FR)* - **FR samples cannot be taken by personnel who generally do the sampling.** They must be taken by or under the direct supervision of the Materials Supervisor or his authorized representative and must not be scheduled on such an inflexible and regular routine that its frequency can be predicted, but sufficient samples must be submitted to satisfy the frequency intended. FR samples are to be taken in accordance with MT-602, section 5.

8.6 *Portland Cement* - Samples will be taken by the Materials Bureau from Montana manufacturers and suppliers. A minimum of two samples will be taken annually, more may be taken if necessary. The purpose of this sampling and testing is to establish agreement between the manufacturer's certifications and the testing done by the Materials Bureau. The Materials Bureau is inspected and accredited by the Cement and Concrete Laboratory (CCRL) as established by the National Bureau of Standards (NBS). Sampling from the project for acceptance purposes will be taken on a random basis by District personnel in accordance with MT-108. Acceptance is based upon conformity to both physical and chemical requirements listed in the specifications.

9 Forms and Reports:

9.1 Regardless of the basis of acceptance, the method of identification of all items incorporated in the project must be documented in the project records.

9.2 Most major materials to be tested have a report form designated for their exclusive use (see MT-513). These forms shall be completed as fully as possible and followed by distribution as indicated.

9.3 Materials not covered by a designated report form must be accompanied by a Miscellaneous Samples Lab Form 45. This form must be fully completed. The form must have the following information: project number, project name, date, name of the sampler, district/area, name of the product, quantity, name and address of the manufacturer, supplier and jobber, and the distribution. In the case of acceptance on the basis of certification or field inspection, a Form 46, 406 or 407 should be used. A remark must be made that a sample is not being submitted and acceptance is on the basis of an authorized prequalification program, manufacturer's certifications or labels.

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Form No. 406

CONTRACTOR'S CERTIFICATE OF COMPLIANCE
FOR NON-STRUCTURAL STEEL & IRON ITEMS
For Compliance with the "Buy America" Provision
Std. Spec 106.09 & 23 CFR 635.410

MDT FIELD ID
DATE-INSPECTOR'S INITIALS

MDT Project No._____Project Name_____

The _____
(Name of Manufacturer/Supplier) **(Address)** **(City, State)** **(Phone)**

has furnished to _____
(Name of Contractor) **(Address)** **(City, State)** **(Phone)**

the following materials for use in the construction of the above referenced project.

MDT Bid Item No.	Product Description	Quantity	Unit LF, YD^2, m, m^3, etc.	Applicable Specification (AASHTO, ASTM, MDT, etc.)

Submit all required documentation with this form. See the back of this form for general guidance on the "Buy America" documentation. Refer to MT 601 for sampling & testing requirements.

Contractor's Statement of Certification

☐ **Domestic Material.** I hereby certify that all manufacturing processes, including application of coating, occurred in the United States for the above listed materials and that those materials do meet all other requirements as set forth in the plans and specifications.

☐ **Non-Domestic Material.** I hereby certify that the above listed materials do meet the requirements as set forth in the plans and specifications with the exception that all or part of the manufacturing process may have occurred outside the United States. The material is considered non-domestic. The cost of this material, including delivery to the project, is _____.

By_____ Title_____
(Contractor's Name, Typed or Printed)

_____ Date _____
(Contractor's Signature)

Note: Two copies of this certificate and attachments must be submitted to the MDT Engineering Project Manager for each type of material before that material can be used on the project. The Prime Contractor is responsible for providing proper documentation to MDT, and payment will be withheld until that documentation is provided.

The form must be completely filled out by the Contractor.

Copies of this form can be obtained from the MDT Materials Bureau, 2701 Prospect Avenue, PO Box 201001, Helena, Montana 59620-1001, or phone (406) 444-6300 or (406)444-6298.

MDT Materials Bureau will conduct random checks of documentation to confirm compliance to the "Buy American" requirement (Std. Spec. 106.09 & 23 CFR 635.410), and may require mill tests at that time. All certifications must have the "domestic steel" statement on them and be signed by a representative of that company. **There is no change in Quality Assurance procedures including sampling and testing requirements (refer to MT 601).**

For Buy America documentation, steel items are divided into 4 categories. A general guide is given below. The category of an item may vary on a case-by-case basis depending on the quantity and usage. The Project Manager determines the category of an item.

1) Structural Members
- Bridge Beams
- Plate Girders
- Piling (Most Items)
- Diaphragms
- Drilled Shaft Casing

2) Fabricated Items
- Cattle guard & Wing Ends
- CSP (Corrugated Steel Pipe)
- Guard Angles
- Guardrail Posts (T-101, etc.)
- Ice Breakers
- Pedestrian Stairway
- SSPP (Struc.Stl. Plate Pipe)
- Trash Guard

3) Fabricated / Manufactured Items
- Butterfly Valves
- Ductile Iron Pipe
- Fluted Steel Piling
- Frang. Sign Post Bkwy.
- Gate Valves
- Guardrail (Most items)
- Impact Attenuators
- Irrigation Canal Gate
- Luminaire Standards and Lighting
- Sign Posts and Bases (Most Items)
- Traffic Signals and Supports

4) Manufactured Items
- Barbwire
- Conduit-Steel
- Delineator Posts
- Fencing (Most Items)
- Smooth Wire
- Stock Tank
- Water Service Line-Steel
- Welded Wire (Most Items)
- Wire Rope (Most Items)
- Miscellaneous Nuts, Bolts, etc.

Some items, like reinforcing steel, will be in different categories for different uses. In major items such as bridges, it should be considered Category 1. In other applications it could be Category 2 or 3 and sometimes Category 4.

The required Buy America documentation varies for these categories.
Category 1 requires full Mill Test Reports and documentation on all other steps in the process.
Category 2 requires this form and material test reports and certifications.
Category 3 requires this form and manufacturers certifications.
Category 4 requires this form.

For non-domestic material, documentation of the cost of the material including delivery to the project is also required.

Note: This form has been approved by FHWA for use on an interim basis. No change is being made to the "Buy America" requirements. This form is only intended to provide guidance and uniformity to the application of the existing specification. A final decision on implementation of this form will be made by June 1, 2003.

Form No. 407

CONTRACTOR'S CERTIFICATE OF COMPLIANCE FOR MISCELLANEOUS ITEMS (NON-STEEL)

MDT ID
DATE-INSPECTOR INITIALS

MDT Project No._____ Project Name_____

The _____
(Name of Manufacturer/Supplier) (Address) (City, State) (Phone)

has furnished to _____
(Name of Contractor) (Address) (City, State) (Phone)

the following materials for use in the construction of the above referenced project.

MDT Bid Item No.	Product Description	Quantity	Unit LF, YD², m, m³, etc.	Supplier	Applicable Spec. (AASHTO, ASTM, MDT, etc).

Product Analysis, Materials Test Reports and other required documentation must be attached to this form. Refer to MT 601 for sampling & testing requirements.

Contractor's Statement of Certification

I hereby certify that the above listed materials do meet the requirements as set forth in the plans and specifications.

By_____ Title_____
(Contractor's Name, Typed or Printed)

_____ Date _____
(Contractor's Signature)

Note: Two copies of this certificate and attachments must be submitted to the MDT Engineering Project Manager for each type of material before that material can be used on the project. The Prime Contractor is responsible for providing proper documentation to MDT, and payment will be withheld until that documentation is provided.

The form must be completely filled by the Contractor. A list of materials, which may be accepted upon receipt of this form and proper documentation, is on the back of this form.

Copies of this form can be obtained from the MDT Materials Bureau, 2701 Prospect Avenue, PO Box 201001, Helena, Montana 59620-1001, or phone (406) 444-6300 or (406) 444-6298.

Form No. 407

The following miscellaneous items may be accepted with the "Contractor's Certificate of Compliance for Miscellaneous Items" (Form 407), including appropriate attachments i.e. Certificates of Analysis, Materials Test Reports, etc. All Certifications from suppliers, fabricators, manufacturers and contractors must be signed by a representative of that company. **There is no change in acceptance, sampling or testing requirements (refer to MT 601).**

Canal Gates
Cl.ass 4 Poles
Concrete Barrier Rail
Concrete Bench
Concrete Culvert
Concrete Picnic Table
Construction Fabrics
Corrugated Aluminum Pipe
Curb-Conc. Median
Deck Seal
Delineators
Edge Drain
Fertilizer
Geo-textiles
HMWM Treatment Material
Inlets
Joint Seals-Silicon
Landscaping
Mailbox
Manholes
Median Rail-Concrete
Mulch
Plastic Pipe
PVC
Reinforced Concrete Pipe
Signs
Sod
Topsoil
Trash Receptacle
Trees & Shrubs
TT Barnpoles
Wood Fence Posts

Note: This form has been approved by FHWA for use on an interim basis. No change is being made to the "Buy America" requirements. This form is only intended to provide guidance and uniformity to the application of the existing specification. A final decision on implementation of this form will be made by June 1, 2003.

NOTE: Numbers in parentheses are page numbers

AGGREGATE:
- Bituminous Treated Base (12)
- Cement Treated Base, Stockpiled (13)
- Cement Treated Base, When Used (13)
- Concrete, During Production of Aggregate (13)
- Concrete, During Production of Concrete for Paving, QA Projects (13)
- Concrete, During Production of Concrete for all Structures (14)
- Concrete, Proposed Source (14)
- Concrete Prepared from Established Source (14)
- Concrete from a New Source (15)
- Crushed Cover Material
  - QA Projects (15)
  - Non-QA Projects (15)
- Open Graded Friction Course
  - QA Projects (15)
  - Non-QA Projects (16)
- Gravel Fill (Bedding & Filter) (16)
- Grout Sand (16)
- Plant Mix Base, Over 500 Tons(when used) (16)
- Plant Mix Base, Under 500 Tons (when used) (17)
- Plant Mix Base & Surfacing (when stockpiled)(17)
- Plant Mix Surfacing (when used)
  - QA Projects (17)
  - Non QA Projects Under 500 Tons (17)
  - Non QA Projects Over 500 Tons (18)
  - Shoulder/Traffic Gravel (18)
  - Preconstruction, Proposed Surfacing Source Samples (18)
  - Surfacing, Not Pre-Approved (18)
- Surfacing, Crushed Base Course, Crushed Top Surfacing, Selected Surfacing, Sand Surfacing
  - Non QA Over 500 tons (18)
  - Non QA Under 500 tons (19)
  - QA Projects (19)

BINDER: (19)

BITUMINOUS MATERIALS:
- Asphalt Cement & Liquid Asphalt
  - Non QA Projects Over 2,000 Gallons (19)
  - Non QA Projects Under 2,000 Gallons (20)
  - QA Projects (20)
- Asphalt Emulsions (20)
- Performance Graded Asphalt Binder - PGAB (120)

BITUMINOUS MIXTURES:
- Density Control (20)
- Bituminous Surface Treatment (20)
- Mineral Filler (21)
- Plant Mix Base (21)
- Plant Mix Surfacing (21)
- Plant Mix Surfacing (Grade "B") (21)
- Plant Mix Surfacing (Grade "C") (21)
- Plant Mix Surfacing (Grade "D") (22)
- Plant Mix Surfacing (SHRP Grade) (22)
- Recycled Pavements (22)
- Seal Coat (SC) (22)

BORROW MATERIAL:
- Special Borrow (22)

BRIDGE HARDWARE:
- Nuts & Bolts (22)
- Direct Tension Indicators (22)
- Expansion Joints (23)
- Elastomeric Bearing Pads (23)
- PVC Waterstop (23)

BUILDING BLOCK & BRICK (23)

CLACIUM/MAGNESIUM CHLORIDE:
- Dust Control, Prime, De-Icer (23)

CATTLE GUARD: (23)

CEMENT:
- Portland (Montana Suppliers) (23)
- Portland (Out-of-State Suppliers) (23)
- Cement Treated Base (Mixture) (24)

CONCRETE:
- Admixtures (Established Sources (24)
- Admixtures (New Sources) (24)
- Air Test & Slump Test (Paving & Structural) (24)
- Cylinders for Statistical Acceptance (Paving) (25)
- Cylinders for Statistical Acceptance (Bridges) (25)
- Cylinders for Structures Designed to Support Loads (25)
- Cylinders for Minor Structures with 50 CYS or more - (Head walls, drop inlets, etc.) (26)
- Culvert, Barrier Rail, Curb, and Other Miscellaneous Precast Items (26)
- Curing Compounds (New Sources) (26)
- Curing Compounds (Established Sources) (26)

NOTE: Numbers in parentheses are page numbers

CONCRETE:
Protective Coatings for Concrete Bridge Structures (Linseed Oil - Boiled) (27)

CONCRETE: (continued)
Water (27)

COPPER:
Water Stop (27)

CRACK SEALER: Hot Poured, Bituminous (27)

CULVERT:
Corrugated Aluminum (27)
Corrugated Steel (27)
Coatings (27)
Corrugated Underdrain (28)
Drain Tile & Drain Pipe (28)
Reinforced Concrete (28)

DENSITY CONTROL:
Bituminous Mixtures
- QA Projects (28)
- Non-QA Projects (28)
Culvert Backfill (28)
Embankment (28)
Surfacing Material, Non-Bituminized (29)

DRAINAGE:
Underdrains – Plastic & Metal (29)

ELECTRICAL:
Conductors & Cables (29)
Conduit (Metal & Plastic) (29)

EPOXY RESIN & ADHESIVE:
For Bonding Fresh to Hardened Concrete (29)
For Bonding Hardened to Hardened Concrete (29)

EXPANSION JOINT FILLER:
Poured (Hot & Cold) (29)
Preformed (Cork, etc.) (30)

FENCING:
Barbed Wire, Woven Wire, Chain Link, Hardware, Tie Wire (30)
Steel Fence Posts (30)
Wood Fence Posts (30)

FERTILIZER:
Under 500 Pounds (30)
Over 500 Pounds (30)

FIBER REINFORCED PADS (30)

FLY ASH:
Blending Material (31)

GEOTEXFILES: CONSTRUCTION:
Woven, Non-Woven (31)
Erosion Control Blankets (31)
Geogrid, Geomembrane (31)

GLASS BEADS (31)

GUARD RAIL & MEDIAN RAIL:
Hardware (31)
Steel (31)
Wire Rope (31)
Wood Posts & Blocks (32)

INSULATION (32)

MULCH (32)

NURSERY STOCK (32)

PAINT:
Traffic (32)
Under 25 Gallons (Non-Traffic) (32)
Over 25 Gallons & Not Pretested (Non-Traffic) (32)

PAVEMENT MARKING MATERIALS:
Epoxy (32)
Preformed Plastic (33)
Thermoplastic (33)

PEAT MOSS (33)

PILING:
Fluted Taper (33)
H Piles (33)
Pre-stressed Concrete (33)

NOTE: Numbers in parentheses are page numbers

PILING:
Round Steel (33)
Treated Timber (33)
Untreated Timber (33)

PIPE:
PVC (34)
Pressure (34)
PVC Water Main) (34)

PLUMBING FIXTURES (34)

PRESTRESS ITEMS:
Concrete Beams (34)
Concrete Piles (34)
Wire Strand (34)

QUARRY:
Geological Reconnaissance for Crushing Sites (34)

REINFORCING STEEL:
Bars (for Field Construction) (34)
Bars, Epoxy Coated (for Field Construction) (34)
Bars (Pre-cast Items) (35)
Steel Mesh (Field Construction) (35)
Steel Mesh (Precast Items) (35)
Wire Rope (35)

RIP-RAP (35)

ROOFING MATERIAL (35)

SEEDING (35)

SHEET ROCK (35)

SIGNS:
Sign & Signing Material (35)

SOD: (35)

SOIL:
Corrosion Testing (36)

STRUCTURAL STEEL:
New Steel (36)
Salvaged (36)

TOP SOIL:
Imported (37)
Salvaged (37)

WATER:
Corrosion Testing (37)

WATER-PROOFING MATERIALS (37)

WEAR:
Crushed Top Surfacing, Type A & B (37)
Crushed Base Coarse, Type A & B (37)

WOOD ITEMS:
Timber (Treated) (37)
Timber (Untreated) (37)

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; BITUMINOUS TREATED BASE – NON QA PROJECTS OVER 500 TONS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208 MT210 MT217 MT219 MT228 MT230	MT201	1 SAMPLE FOR EACH 1,500 TONS (750 CUBIC YARDS) FOR THE FIRST 7,500 TONS (3,750 CUBIC YARDS), AND 1 SAMPLE FOR EACH 2,500 TONS (1,250 CUBIC YARDS) OVER 7,500 TONS (3,750 CUBIC YARDS) THEREAFTER FOR EACH TYPE OF MATERIAL.	IA SAMPLES - 1 SAMPLE FOR EACH 50,000 TONS (25,000 CUBIC YARDS) FOR THE FIRST 100,000 TONS (50,000 CUBIC YARDS), THEN 1 SAMPLE FOR EACH 100,000 TONS (50,000 CUBIC YARDS) THEREAFTER FOR EACH TYPE OF MATERIAL. FR - 1 SAMPLE FOR EACH 4 MILES OF 2-LANE ROADWAY.	IA SAMPLES - 1 SAMPLE FOR EACH 50,000 TONS (25,000 CUBIC YARDS) FOR THE FIRST 100,000 TONS (50,000 CUBIC YARDS), THEN 1 SAMPLE FOR EACH 100,000 TONS (50,000 CUBIC YARDS) THEREAFTER FOR EACH TYPE OF MATERIAL.
AGGREGATE; BITUMINOUS TREATED BASE – NON QA PROJECTS UNDER 500 TONS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208 MT210 MT217 MT219 MT228 MT230	MT201	SEE SPECIAL PROVISIONS.	FR - 1 SAMPLE FOR EACH 4 MILES OF 2-LANE ROADWAY, MINIMUM OF 1 PER PROJECT CONTRACT.	
AGGREGATE; BITUMINOUS TREATED BASE – QA PROJECTS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208 MT210 MT217 MT219 MT228 MT230	MT202	1 SAMPLE FOR EACH 2,500 TONS (1,250 CUBIC YARDS); ONE LOT = 5 SAMPLES OR APPROXIMATELY 12,500 TONS (6,250 CUBIC YARDS).	1 SAMPLE FOR EACH 6 LOTS (MINIMUM OF 1 PER PROJECT). FR - 1 SAMPLE FOR EACH 4 MILES OF 2-LANE ROADWAY, MINIMUM OF 1 PER PROJECT/CONTRACT.	1 IA SAMPLE FOR EACH 6 LOTS, MINIMUM OF 1 PER PROJECT/CONTRACT.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; CEMENT TREATED BASE – STOCKPILED STD. SPEC. 701	SAMPLE MT216 TEST MT216	300 LB. SAMPLE EA. SOURCE OR EA. TYPE FOR MIX DESIGN	1 SAMPLE PER PROJECT/CONTRACT		TESTED AND MIX DESIGN ISSUED.
AGGREGATE; CEMENT TREATED BASE - WHEN USED STD. SPEC. 701	SAMPLE MT216 TEST MT216		1 SAMPLE FOR EACH 2,500 TONS (1,250 CUBIC YARDS). 5 SAMPLES PER LOT.	1 – IA FOR EACH 5 LOTS, MIMIMUM 1 PER PROJECT/ CONTRACT.	1 – IA FOR EACH 5 LOTS, MIMIMUM 1 PER PROJECT/ CONTRACT.
AGGREGATE; CONCRETE AGGREGATE DURING THE PRODUCTION OF AGGREGATE STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT203 MT204 MT205 MT215	MT201	1 SAMPLE FOR EACH SIZE TO BE SUBMITTED TO DISTRICT/AREA LAB FOR TESTING. NOTE: CONTINUOUS SAMPLING DURING PRODUCTION TO CHECK MATERIAL.	1 SAMPLE FOR EACH SIZE.	
AGGREGATE; CONCRETE AGGREGATE, DURING THE PRODUCTION OF CONCRETE FOR PAVING - QA PROJECTS STD. SPEC. 501	SAMPLE MT201 TEST MT202 MT203 MT204 MT205 MT215	MT201	MINIMUM OF 3 SAMPLES PER DAY. NOTE: SAMPLES SHALL BE TAKEN FROM THE STORAGE BIN AT THE POINT OF MIXING OR FROM THE DEVICE THAT CHARGES THE STORAGE BIN. ANY DEVIATION FROM THIS SAMPLING PROCEDURE MUST BE APPROVED BY THE MATERIALS ENGINEER.	NOTE: THE DISTRICT/AREA LAB WILL TAKE SAMPLES IN THE EVENT THAT FIELD PERSONNEL ARE UNABLE TO SO.	IA SAMPLES - 1 SAMPLE OF EACH SIZE FOR EACH TWO LANE MILE, MINIMUM OF 1 SAMPLE FOR PROJECTS LESS THAN 1 MILE.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; CONCRETE AGGREGATE, DURING THE PRODUCTION OF CONCRETE FOR ALL STRUCTURES STD. SPEC. 701	SAMPLE MT201 MT201 TEST MT202 MT203 MT204 MT205 MT215	MT201	1 SAMPLE OF EACH SIZE FOR EACH 125 CYS. OF CONCRETE WITH A MINIMUM OF 1 SAMPLE FOR EACH SIZE PER PROJECT. NOTE: SAMPLES WILL BE TAKEN FROM THE STORAGE BIN AT THE POINT OF MIXING OR FROM THE DEVICE THAT CHARGES THE STORAGE BIN. ANY DEVIATION FROM THIS SAMPLING PROCEDURE MUST BE APPROVED BY THE MATERIALS ENGINEER.	1 SAMPLE OF EACH SIZE FOR EACH 125 CYS. OF CONCRETE WITH A MINIMUM OF 1 SAMPLE FOR EACH SIZE PER PROJECT. NOTE: SAMPLES WILL BE TAKEN FROM THE STORAGE BIN AT THE POINT OF MIXING OR FROM THE DEVICE THAT CHARGES THE STORAGE BIN. ANY DEVIATION FROM THIS SAMPLING PROCEDURE MUST BE APPROVED BY THE MATERIALS ENGINEER.	IA SAMPLES - AT LEAST 1 SAMPLE OF EACH SIZE OR EVERY 4TH SAMPLE OF EACH SIZE, MINIMUM OF 1 PER PROJECT/CONTRACT.
AGGREGATE; CONCRETE AGGREGATE, PROPOSED SOURCE (PIT SAMPLES) STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT203 MT204 MT205 MT209	MT201		3 - 60 LB. COMPOSITE SAMPLES FROM EACH SOURCE.	
AGGREGATE: CONCRETE AGGREGATE, FROM AN ESTABLISHED SOURCE STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT203 MT204 MT205 MT219	MT201		3 - 30 LB. SAMPLES OF FINE AGGREGATE AND 3 - 60 LB. SAMPLES OF MEDIUM AND COARSE AGGREGATE FOR EACH CONSTRUCTION SEASON FOR MIX DESIGN CHECK AND QUALITY CONTROL.	

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; CONCRETE AGGREGATE, FROM A NEW SOURCE STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT203 MT204 MT205 MT209 MT215	MT201		3 - 30 LB. SAMPLES OF FINE AGGREGATE AND 3 - 60 LB. SAMPLES OF MEDIUM AND COARSE AGGREGATE.	
AGGREGATE; CRUSHED COVER MATERIAL - QA PROJECTS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208 MT209 MT217 MT227 MT228 MT305	MT201	1 SAMPLE FOR EACH 500 TONS (250 CUBIC YARDS); 1 LOT = 5 SAMPLES OR APPROXIMATELY 2,500 TONS (1,250 CUBIC YARDS).	1 SAMPLE FOR EACH LOT.	1 - 150 LB. SAMPLE FROM STOCKPILE FOR DESIGN IA SAMPLES - 1 FOR EACH PROJECT/CONTRACT.
AGGREGATE; CRUSHED COVER MATERIAL - NON QA PROJECTS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208 MT209 MT217 MT227 MT228 MT305	MT201	1 SAMPLE FOR EACH 500 TONS (250 CUBIC YARDS).	1 SAMPLE FOR EACH 2,000 TONS (1,000 CUBIC YARDS) OR 1 SAMPLE FOR EACH SOURCE.	1 - 150 LB. SAMPLE FROM STOCKPILE FOR DESIGN IA SAMPLES - 1 SAMPLE FOR EACH PROJECT/CONTRACT.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; OPEN GRADED FRICTION COURSE - QA PROJECTS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208 MT217 MT315	MT201	1 SAMPLE FOR EACH 400 TONS (200 CUBIC YARDS, 1 LOT = 5 SAMPLES OR APPROXIMATELY 2,000 TONS (1,000 CUBIC YARDS). NOTE: 2 SAMPLES PER PROJECT WILL BE TAKEN FOR FRACTURE, GRADATION AND ADHESION.	400 LBS. FROM STOCKPILE FOR DESIGN. 1 - 30 LB. SAMPLE FOR EVERY 2 LOTS.	1 - 30 LB. SAMPLE PER PROJECT FOR GRADATION, FRACTURE AND ADHESION. IA SAMPLES - 2 FOR EACH PROJECT/CONTRACT.
AGGREGATE; OPEN GRADED FRICTION COURSE - NON QA PROJECTS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT209 MT213 MT227	MT201	1 SAMPLE FOR EACH 1,000 TONS (500 CUBIC YARDS). NOTE: 2 SAMPLES PER PROJECT WILL BE TAKEN FOR FRACTURE, GRADATION AND ADHESION.	400 LBS. FROM THE STOCKPILE FOR DESIGN. 1 SAMPLE FOR EACH 4,000 TONS (2,000 CUBIC YARDS) 1 - 30 LB. SAMPLE FOR GRADATION, ADHESION AND FRACTURE.	IA SAMPLES - 2 PER PROJECT/ CONTRACT.
AGGREGATE; GRAVEL FILL (BEDDING AND FILTER) STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208	MT201		MINIMUM OF 1 SAMPLE PER SOURCE. TESTING AND ACCEPTANCE ISSUED BY DISTRICT/AREA LAB.	
AGGREGATE; GROUT SAND STD. SPEC. 701	SAMPLE MT201 TEST MT202	MT201		1 - 30 LB. SAMPLE FROM EACH SOURCE.	
AGGREGATE; PLANT MIX BASE, OVER 500 TONS (WHEN USED) BY SPECIAL PROVISION	SAMPLE MT201 TEST MT202 MT208 MT213 MT217 MT305	MT201 MT202	1 SAMPLE FOR EACH 500 TONS (250 CUBIC YARDS) OR EVERY 2 HOURS.	1 SAMPLE FOR EACH 5,000 TONS (2,500 CUBIC YARDS) (SEE MT201, 16.1) 2 SAMPLES FOR EACH PROJECT FOR VOLUME SWELL AND FRACTURE. IA SAMPLES - 1 EVERY 4TH SAMPLES, MINIMUM OF ONE FOR EACH PROJECT/CONTRACT.	1 – 500 LB. SAMPLE FROM THE STOCKPILE FOR DESIGN IA SAMPLES - 1 EVERY 4TH SAMPLE, MINIMUM OF ONE FOR EACH PROJECT/CONTRACT.

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; PLANT MIX BASE, UNDER 500 TONS (WHEN USED) BY SPECIAL PROVISION	SAMPLE MT201 TEST MT202 MT208 MT213 MT217 MT305	SEE SPECIAL PROVISIONS	SEE SPECIAL PROVISIONS.		IA SAMPLES – MINIMUM OF 1 PER PROJECT/CONTRACT.
AGGREGATE; PLANT MIX BASE, PLANT MIX SURFACING (WHEN STOCKPILED) STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT217 MT305	25 LB. FOR EACH 1,000 TONS	MINIMUM OF 5 SAMPLES PER PROJECT FOR VOLUME SWELL AND FRACTURE. NOTE: SEE SPECIAL PROVISIONS.	MINIMUM OF 5 SAMPLES PER PROJECT (AS DETERMINED NECESSARY FOR FRACTURE AND VOLUME SWELL).	MINIMUM OF 5 SAMPLES PER PROJECT (AS DETERMINED NECESSARY FOR FRACTURE AND VOLUME SWELL).
AGGREGATE; PLANT MIX SURFACING QA PROJECTS (WHEN USED) STD. SPEC. 701	SAMPLE MT201 MT202 TEST MT202 MT208 MT213 MT217 MT305	MT201 MT202	1 SAMPLE FOR EACH 600 TONS (300 CUBIC YARDS), ONE LOT = 5 SAMPLES OR APPROXIMATELY 3,000 TONS (1,500 CUBIC YARDS).	1 SAMPLE FOR EVERY 2 LOTS 2 SAMPLES PER PROJECT FOR VOLUME SWELL AND FRACTURE IA SAMPLES – 1 FOR EVERY 6 LOTS, MINIMUM OF 1 PER PROJECT/ CONTRACT.	1 – 500 LB. SAMPLE FROM THE STOCKPILE FOR DESIGN 2 SAMPLES PER PROJECT FOR VOLUME SWELL AND FRACTURE IA SAMPLES - 1 FOR EVERY 6 LOTS, MINIMUM OF 1 PER PROJECT/CONTRACT.
AGGREGATE; PLANT MIX SURFACING - NON QA PROJECTS (UNDER 500 TONS) STD. SPEC. 701	SAMPLE MT201 MT202 TEST MT202 MT208 MT213 MT217 MT305	MT201 MT202	SEE SPECIAL PROVISIONS.		IA SAMPLES – MINIMUM OF 1 PER PROJECT/CONTRACT.

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; PLANT MIX SURFACING - NON QA PROJECTS (OVER 500 TONS) STD. SPEC. 701	SAMPLE MT201 MT202 TEST MT202 MT208 MT213 MT217 MT305	MT201 MT202	1 SAMPLE FOR EACH 500 TONS (250 CUBIC YARDS) OR 1 SAMPLE EVERY 2 HOURS (SEE MT201, 16.1).	1 SAMPLE FOR EACH 5,000 TONS (2,500 CUBIC YARDS) 2 SAMPLES PER PROJECT FOR VOLUME SWELL AND FRACTURE IA SAMPLES - 1 SAMPLE EVERY 4TH SAMPLE, MINIMUM OF 1 PER PROJECT/CONTRACT.	1 - 500 LB. SAMPLE FROM THE STOCKPILE FOR DESIGN 2 SAMPLES PER PROJECT FOR VOLUME SWELL AND FRACTURE IA SAMPLES - 1 SAMPLE EVERY 4TH SAMPLE, MINIMUM OF 1 PER PROJECT/CONTRACT.
AGGREGATE; SHOULDER GRAVEL, TRAFFIC GRAVEL	SAMPLE MT201 TEST MT202	MT210 MT202	MINIMUM OF 1 SAMPLE PER PROJECT/CONTRACT, RESAMPLE IF MATERIAL CHANGES. SEE SPECIAL PROVISIONS.		
AGGREGATE; PROPOSED SURFACING SOURCE SAMPLES STD. SPEC. 701	MT201	MT201		TEST FOR GRADATION, LL, PI, AND VOLUME SWELL.	ACCEPTANCE BASED ON SATISFACTORY TEST RESULTS.
AGGREGATE; SURFACING, NOT PRE-APPROVED	MT201	MT201		5 RANDOM SAMPLES PER PROJECT/CONTRACT.	ACCEPTANCE BASED ON SATISFACTORY WEAR TEST RESULTS.
AGGREGATE; SURFACING; CRUSHED BASE COURSE, CRUSHED TOP SURFACING, SELECTED SURFACING, SAND SURFACING, NON QA PROJECTS OVER 500 TONS STD. SPEC. 701	SAMPLE MT201 MT202 TEST MT202 MT208 MT210 MT217 MT219 MT228 MT230	MT201	1 SAMPLE FOR EACH 1,500 TONS (750 CUBIC YARDS) FOR THE FIRST 7,500 TONS (3,750 CUBIC YARDS) AND 1 SAMPLE FOR EACH 2,500 TONS (1,250 CUBIC YARDS) OVER 7,500 TONS (3,750 CUBIC YARDS) THEREAFTER FOR EACH TYPE OF MATERIAL.	IA SAMPLES - 1 SAMPLE FOR EACH 50,000 TONS (25,000 CUBIC YARDS) FOR THE FIRST 100,000 TONS (50,000 CUBIC YARDS), THEN 1 SAMPLE FOR EACH 100,000 TONS (50,000 CUBIC YARDS) FOR EACH TYPE OF MATERIAL THEREAFTER.	IA SAMPLES - 1 SAMPLE FOR EACH 50,000 TONS (25,000 CUBIC YARDS) FOR THE FIRST 100,000 TONS (50,000 CUBIC YARDS), THEN 1 SAMPLE FOR EACH 100,000 TONS (50,000 CUBIC YARDS) FOR EACH TYPE OF MATERIAL THEREAFTER. IA SAMPLES – MINIMUM OF 1 PER PROJECT/CONTRACT.

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; SURFACING; CRUSHED BASE COURSE, CRUSHED TOP SURFACING, SELECTED SURFACING, SAND SURFACING, NON QA PROJECTS UNDER 500 TONS STD. SPEC. 701	SAMPLE MT201 MT202 TEST MT202 MT208 MT210 MT217 MT219 MT228 MT230	MT201	SEE SPECIAL PROVISIONS.		IA SAMPLES – MINIMUM OF 1 PER PROJECT/CONTRACT.
AGGREGATE; SURFACING; CRUSHED BASE COURSE, CRUSHED TOP SURFACING, SELECTED SURFACING, SAND SURFACING, QA PROJECTS STD. SPEC. 701	SAMPLE MT201 MT202 TEST MT202 MT208 MT210 MT217 MT219 MT228 MT230	MT201	1 SAMPLE FOR EACH 2,500 TONS (1,250 CUBIC YARDS), ONE LOT = 5 SAMPLES OR APPROXIMATELY 12,500 TONS (6,250 CUBIC YARDS).	IA SAMPLES - 1 SAMPLE FOR EACH 6 LOTS, MINIMUM OF 1 SAMPLE PER PROJECT/CONTRACT.	IA SAMPLES - 1 SAMPLE FOR EACH 6 LOTS, MINIMUM OF 1 SAMPLE PER PROJECT/CONTRACT.
BINDER STD. SPEC. 301	SAMPLE MT201 TEST MT201	25 LB.	SEE MT201, PARAGRAPH 8.		
BITUMINOUS MATERIALS; LIQUID ASPHALT, NON QA PROJECTS OVER 2,000 GAL. STD. SPEC. 702	SAMPLE MT302	2-1 QUART SAMPLES	2 QUARTS FROM EACH SHIPMENT OVER 2,000 GALLONS TO MATERIALS BUREAU.		IA SAMPLES - FOR PROJECTS OVER 20,000 GALLONS, 1 QUART FOR EACH 200,000 GALLONS.

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
BITUMINOUS MATERIALS; LIQUID ASPHALT, NON QA PROJECTS UNDER 2,000 GAL. STD. SPEC. 702		NONE	CERTIFICATE OF COMPLIANCE REQUESTED.		
BITUMINOUS MATERIALS; LIQUID ASPHALT, QA PROJECTS STD. SPEC. 702		1-QUART IN METAL CAN	1 - 1 QUART SAMPLE FOR EACH 500 TONS OF PLANT MIX, ONE LOT = 6 SAMPLES OR APPROXIMATELY 3,000 TONS. NOTE: FOR GRADE "C" BITUMINOUS MIXTURES REFER TO SPECIAL PROVISIONS.		IA SAMPLES - 1 SAMPLE FOR EVERY 5 LOTS TO MATERIALS BUREAU.
BITUMINOUS MATERIALS; ASPHALT EMULSIONS STD. SPEC. 702	SAMPLE MT302	2-1 QUART SAMPLES IN PLASTIC BOTTLES	2 – 1 QUART SAMPLES TAKEN FROM THE TANKER OR TRAILER.		I.A. SAMPLES - FOR PROJECTS OVER 20,000 GALS., 1 SAMPLE FOR THE FIRST 100,000 GALS. AND 1 SAMPLE FOR EACH 100,000 GALS. THEREAFTER.
BITUMINOUS MATERIALS; PERFORMANCE GRADED ASPHALT BINDER (PGAB)	SPECIAL PROVISION	2-1 PINT METAL CANS	SEE SPECIAL PROVISIONS		
BITUMINOUS MIXTURES; DENSITY CONTROL, QA PROJECTS STD. SPEC. 401	SAMPLE MT212 OR CORES TEST MT212 MT313	MT212 MT313	1 TEST FOR EACH 600 TONS OF MIX; LOT = 5 TESTS OR APPROX. 3,000 TONS OF MIX.	IA SAMPLES - SEE MT317.	
BITUMINOUS MIXTURES; BITUMINOUS SURFACE TREATMENTS (BST) STD. SPEC. 410			SEE "BITUMINOUS MATERIALS". SEE "CRUSHED COVER AGGREGATE".		

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
BITUMINOUS MIXTURES; MINERAL FILLER (HYDRATED LIME, FLY ASH, ETC.) STD. SPEC. 713	SAMPLE MT201 TEST MT301	MT201			1 – 5 LB. SAMPLE PER PROJECT/CONTRACT.
BITUMINOUS MIXTURES; PLANT MIX BASE BY SPECIAL PROVISION	SAMPLE MT212 OR CORES TEST MT212 MT313				500 LB. SAMPLE IS REQUIRED FOR MIX DESIGN. SAMPLE MUST INCLUDE AGGREGATE, MINERAL FILLER AND ASPHALT TYPE.
BITUMINOUS MIXTURES; PLANT MIX SURFACING GRADE "B" STD. SPEC. 401				FINAL RECORD SAMPLE - 2 CORES PER 2 LANES TAKEN IN ALTERNATING LANES AT 1/2-MILE INTERVALS.	500 LB. SAMPLE IS REQUIRED FOR MIX DESIGN. SAMPLE MUST INCLUDE AGGREGATE, MINERAL FILLER AND ASPHALT TYPE.
BITUMINOUS MIXTURES; PLANT MIX SURFACING, "GRADE C" BY SPECIAL PROVISION	SAMPLE MT322 TEST MT306		IGNITION OVEN (1 SAMPLE FOR EACH 500 TONS OF MIX) ACCEPTANCE SAMPLE SIZE AND FREQUENCY IS DETERMINED BY MAINT. SUPERVISOR OR ENGINEER. NOTE: SEE "SPECIAL PROVISIONS" FOR MARSHALL PROPERTIES AND PLANT PRODUCTION REQUIREMENTS.	SAMPLE AND TEST AT DISTRICT'S DISCRETION. FINAL RECORD SAMPLES - 2 CORES PER 2 LANES TAKEN IN ALTERNATING LANES AT 1/2-MILE INTERVALS.	350 LB. SAMPLE IS REQUIRED FOR MIX DESIGN, SAMPLE MUST INCLUDE AGGREGATE, MINERAL FILLER AND ASPHALT TYPE -- NOTE: MIX DESIGNS TRANSFERRED FROM OTHER PROJECTS MUST BE APPROVED BY THE MATERIALS ENGINEER.

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
BITUMINOUS MIXTURES; PLANT MIX SURFACING GRADE "D" BY SPECIAL PROVISION				FINAL RECORD SAMPLES - 2 CORES PER 2 LANE MILE TAKEN AT 1/2-MILE INTERVALS.	1,500 LB. SAMPLE FOR MIX DESIGN, SAMPLE MUST INCLUDE AGGREGATE, MINERAL FILLER AND ASPHALT TYPE.
BITUMINOUS MIXTURES; PLANT MIX SURFACING GRADE "S" BY SPECIAL PROVISION				FINAL RECORD SAMPLES - 2 CORES PER 2 LANE MILE TAKEN AT 1/2-MILE INTERVALS.	1,500 LB. SAMPLE FOR MIX DESIGN, SAMPLE MUST INCLUDE AGGREGATE, MINERAL FILLER AND ASPHALT TYPE.
BITUMINOUS MIXTURES; RECYCLED PAVEMENTS BY SPECIAL PROVISION	SAMPLE MT201 MT316	MT316	SAMPLES FOR PROPOSED RECYCLE PAVEMENT, RECYCLED MIX DESIGN, RECYCLED PAVEMENT PRODUCTION. CONTROL SHALL BE TAKEN IN ACCORDANCE WITH MT316.	FINAL RECORD SAMPLES - 2 CORES PER 2 LANE MILE TAKEN AT 1/2-MILE INTERVALS.	
BITUMINOUS MIXTURES; SEAL COAT (SC) STD. SPEC. 409			SEE "BITUMINOUS MATERIALS" SEE "AGGREGATE, CRUSHED COVER MATERIAL".		
BORROW MATERIAL; SPECIAL BORROW STD. SPEC. 203	SAMPLE MT201 TEST MT202 MT208	MT201	SEE "SPECIAL PROVISIONS".	DETERMINE LL, PI, SOIL CLASS AND GRADATION USING THE FIELD SAMPLE SEE "SPECIAL ROVISIONS". IA SAMPLES – ONLY IF GRADATIONS REQUIRED FOR ACCEPTANCE.	SEE "SPECIAL PROVISIONS". IA SAMPLES – ONLY IF GRADATIONS REQUIRED FOR ACCEPTANCE.
BRIDGE HARDWARE; NUTS AND BOLTS STD. SPEC. 556	SAMPLE M292 ASTM A325	M292 ASTM A325	SEE SPECIAL PROVISIONS.		ACCEPTED BASED ON MANU-FACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
BRIDGE HARDWARE; DIRECT TENSION INDICATORS BY SPECIAL PROVISION	SAMPLE ASTM F959	ASTM F959	SEE SPECIAL PROVISIONS.		ACCEPTED BASED ON MANU-FACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
BRIDGE HARDWARE; EXPANSION JOINTS STD. SPEC. 707	SPECIAL PROVISION		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND FIELD INSPECTION FORM 46.		SUBJECT TO TESTING WHEN REQUESTED.
BRIDGE HARDWARE; ELASTOMERIC BEARING DEVICES STD. SPEC. 711	AASHTO M251		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND FIELD INSPECTION FORM 46.		SUBJECT TO TESTING WHEN REQUESTED.
BRIDGE HARDWARE; PVC WATERST0P STD. SPEC. 707	ASTM D412,D746 D2240		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND FIELD INSPECTION FORM 46.		SUBJECT TO TESTING WHEN REQUESTED.
BUILDING BLOCK AND BRICK; BY SPECIAL PROVISION OR PLANS			SAMPLES WILL BE TAKEN AT RANDOM AND ACCEPTANCE ISSUED ON FIELD INSPECTION, DIST. LAB REPORTS OR MANUFACTURER'S CERTIFICATION.		
CALCIUM/MAGNESIUM CHLORIDE; DUST CONTROL, PRIME, DEICER		½ PINT	DETERMINE SPECIFIC GRAVITY FOR EACH DISTRIBUTOR LOAD, ACCEPT ON FORM 46. IF SAMPLE FAILS, SUBMIT FIRST SAMPLE AND ONE EVERY 400 TONS FROM DISTRIBUTOR OR WHEN TAKEN FROM DIFFERENT TANKER/RAIL CAR. SAMPLE TO MATERIALS BUREAU ON FORM 45 WITH CERT FOR TESTING.		
CATTLE GUARD STD. SPEC. 611					MATERIALS BUREAU WILL MAKE ARRANGEMENTS FOR INSPECTION.
CEMENT; PORTLAND CEMENT MONTANA SUPPLIERS STD. SPEC. 551	SAMPLE MT108	MINIMUM 15 LBS.		RANDOM SAMPLES ACCORDING TO MT108.	ACCEPTANCE BASED ON MANU-FACTURER'S CERTIFICATION AND TESTS BY THE MATERIALS BUREAU. NOTE: SEE MT108.
CEMENT; PORTLAND CEMENT OUT-OF-STATE SUPPLIERS STD. SPEC. 551					MATERIALS BUREAU NEEDS TO BE NOTIFIED TO MAKE ARRANGEMENTS FOR PRETESTING.

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
CEMENT; CEMENT TREATED BASE MIXTURE STD. SPEC. 304	SAMPLE MT108 MT216 TEST MT202 MT216	2 SPECIMENS	ONE 7 DAY AND ONE 28 DAY COMPRESSION SPECIMEN FOR EACH 2 LANE MILE FOR EACH LIFT -- NOTE: SEE SPECIAL PROVISIONS FOR CEMENT CONTENT TESTING REQUIREMENTS.		
CONCRETE: ADMIXTURES - ESTABLISHED SOURCES STD. SPEC. 551	NONE	NONE			ACCEPTED ON MANUFACTURER'S CERTIFICATIONS AND SATISFACTORY FIELD PERFORMANCE.
CONCRETE: ADMIXTURES - NEW SOURCES STD. SPEC. 551		1 QUART	1 QUART FROM THE FIRST SHIPMENT WITH MANUFACTUER'S CERTIFICATION.		
CONCRETE; AIR AND SLUMP TEST (PAVING AND STRUCTURAL) STD. SPEC. 551	SAMPLE MT102 MT104 MT105 TEST MT102 MT104	MT105	ONE AIR AND SLUMP TEST ON THE 1ST THREE LOADS OF EA. CLASS FRESH CONC., THEN A MIN. OF ONE TEST FOR EA. 100 CYS. OR PORTION THEREOF. AT LEAST ONE TEST PER DAY OF POUR IS REQUIRED. IF THE 1ST TEST SAMPLE FAILS, TESTS MUST BE PERFORMED FOR THE 2ND AND 3RD LOADS. EACH TEST WILL BE MADE USING FRESH CONCRETE.	I.A. TESTING - ONE AIR AND SLUMP TEST PER 500 CYS. OR A MIN. OF ONE PER MAJOR STR. ONE TEST PER TWO MILES OF 2-LANE PAVING OR MIN. OF ONE PER PROJECT/CONTRACT.	

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
CONCRETE; CYLINDERS FOR STATISTICAL ACCEPTANCE (PAVING) STD. SPEC. 551	SAMPLE MT105 MT416 TEST MT101 MT102 MT104 MT105	MT105	TWO SETS OF CYLINDERS PER LOT - SEE ARTICLE 551.03.7 OF THE MONTANA SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION FOR LOT SIZE AND SIZE OF SET.	I.A. SAMPLES - ONE PER TWO MI. OF 2-LANE ROADWAY WITH A MIN. OF ONE PER PROJECT/CONTRACT.	
CONCRETE: CYLINDERS FOR STATISTICAL ACCEPTANCE (BRIDGES) STD. SPEC. 551	SAMPLE MT105 MT416 TEST MT101 MT102 MT104 MT105	MT105	TWO SETS OF CYLINDERS PER LOT - SEE ARTICLE 551.03.7 OF THE MONTANA SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION FOR LOT SIZE AND SIZE OF SET.	I.A. SAMPLES - ONE SAMPLE FOR EACH 500 CUBIC YARDS OR A MINIMUM OF ONE FOR EACH MAJOR STRUCTURE.	
CONCRETE; CYLINDERS FOR STRUCTURES DESIGNED TO SUPPORT LOADS STD. SPEC. 552	SAMPLE MT105 MT416 TEST MT101 MT102 MT104 MT105	MT105	ONE SET OF THREE CYLINDERS FOR EACH 100 CUBIC YARDS OR ANY FRACTION THEREOF FOR EACH DAY'S POUR. NOTE: THIS APPLIES TO NON-BRIDGE DESIGNED LOAD-BEARING ITEMS -- RETAINING WALLS, BUILDING FOUNDATIONS, CATTLE GUARD BASES, CULVERT FOUNDATION, AND TO CLASS AS OR BD CONRETE FOR BRIDGES.		

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
CONCRETE; CYLINDERS FOR MINOR STRUCTURES WITH 50 CUBIC YARDS OR MORE STD. SPEC. 552	SAMPLE MT105 MT416 TEST MT101 MT102 MT104 MT105	MT105	ONE SET OF THREE CYLINDERS FROM FIRST POUR WITH EA. CLASS AND ONE SET PER EA. 100 CU. YD. PER EA. 100 CU. YD. PER EA. CLASS THEREAFTER.NOTE: THIS INCLUDES SUCH ITEMS AS CURBS, SIDEWALKS, IRRIGATION STRUCTURES,FOUNDATIONS, SLOPE PROTECTION, CULVERT HEADWALLS, ECT. CYLINDERS ARE MAINLY TO VERIFY MIX DESIGN, PRIMARY ACCEPTANCE IS ON BATCH INSP., AIR AND SLUMP TESTS ON EA. POUR. ACCEPTANCE OF CONC. IN PRECAST ITEMS WILL BE ON BASIS OF FIELD CURED CYL. SEE STANDARD SPECIFICATIONS, SECTION 554.03.6.	I.A. SAMPLE - ONE PER 500 CYS. WITH A MINIMUM OF ONE SET.	
CONCRETE; CONCRETE CULVERT, STD. SPEC. 708, BARRIER RAIL, CURB AND OTHER MISC. PRECAST ITEMS STD. SPEC. 554	SAMPLE MT110 TEST MT110 AASHTO T-22		A VISUAL INSPECTION WILL BE CONDUCTED ON ITEMS DELIVERED TO THE PROJECT. NOTE: ALL ITEMS SHOULD BE STAMPED WITH A CIRCLE M (M).	THE TESTING AND INSPECTION OF CONCRETE PIPE AND ASSOCIATED ITEMS WILL BE DONE BY DISTRICT LABORATORIES WHERE CONCRETE PLANTS ARE LOCATED. SEE STANDARD SPEC. 554.	MATERIALS BUREAU WILL TEST AND INSPECT AT THE ELK RIVER PLANT IN HELENA.
CONCRETE; CURING COMPOUNDS, NEW SOURCES STD. SPEC. 551		1 QUART	SAMPLE AT RANDOM FROM FIRST SHIPMENT.		
CONCRETE; CURING COMPOUNDS, ESTABLISHED SOURCES STD. SPEC. 551		NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION. SEE ESTABLISHED PRODUCTS LIST.		

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
CONCRETE; PROTECTIVE COATINGS FOR CONCRETE BRIDGE STRUCTURES (BOILED LINSEED OIL, MINERAL SPIRITS) STD. SPEC. 551		1 QUART			ACCEPTED BASED ON MANUFACTUER'S CERTIFICATION AND SATISFACTORY TEST RESULTS. SEE NOTE 5.
CONCRETE; WATER FOR CONCRETE STD. SPEC. 551	SAMPLE MT109	1 QUART	1 QUART WHEN WATER QUALITY IS DOUBTFUL AND 1 QUART FROM EACH NEW SOURCE TO MATERIALS BUREAU.		
COPPER: WATER STOP (SHEET COPPER) STD. SPEC. 707		1-12"x12"	FABRICATION CHECK.	1 RANDOM SAMPLE FOR EACH SHIPMENT INCLUDING MANUFACTUER'S CERTIFICATION. NOTE: WEIGHT PER SQUARE FOOT AND GAUGE CHECK.	1 RANDOM SAMPLE FOR EACH SHIPMENT INCLUDING MANUFACTUER'S CERTIFICATION NOTE: NO SAMPLE REQUIRED IF TESTED BY THE DISTRICT.
CRACK SEALER; HOT POURED, BITUMINOUS PRETESTRED		30 LBS.	1 SAMPLE FROM THE FIRST LOT FOR PRETESTING WITH MANUFACTURER'S CERTIFICATION		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
CRACK SEALER; HOT POURED, BITUMINOUS		2 – 1 QT. CANS	1 SAMPLE FOR EACH LOT TAKEN AT THE POINT OF APPLICATION WITH MANUFACTURER'S CERTIFICATION		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
CULVERT; CORRUGATED ALUMINUM STD. SPEC. 603	MT401	MT401	VISUAL INSPECTION.	INSPECTION AT POINT OF MANUFACTURE WITH MILL TEST REPORTS SUBMITTED BY FABRICATOR.	
CULVERT; CORRUGATED STEEL STD. SPEC. 603	MT402	MT402	VISUAL INSPECTION.	INSPECTION AT POINT OF MANUFACTURE WITH MILL TEST REPORTS SUBMITTED BY FABRICATOR.	
CULVERT; COATING STD. SPEC. 603		1 LB. SAMPLE	1 SAMPLE FOR EACH LOT OR BATCH.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
CULVERT; CORRUGATED UNDERDRAIN STD. SPEC. 603		1 - 3 FT. SECTION	1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
CULVERT; DRAIN TILE & DRAIN PIPE STD. SPEC. 603	NONE	NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND FIELD INSPECTION REPORT.		RANDOM SPOT CHECKS.
CULVERT; REINFORCED CONCRETE STD. SPEC. 603	MT110	NONE	VISUAL INSPECTION.	ACCEPTED ON INSPECTION REPORT AT POINT OF MANUFACTURE.	ACCEPTED ON INSPECTION REPORT AT POINT OF MANUFACTURE.
DENSITY CONTROL; BITUMINOUS MIXTURES QA PROJECTS STD. SPEC. 401	SAMPLE MT212 TEST MT313	MT212	1 TEST FOR EACH 600 TONS OF MIX; 1 LOT = 5 TESTS OR APPROXIMATELY 3,000 TONS OF MIX. FR SAMPLE - CORE ACCORDING TO MT317.	NOTE: DISTRICT MAY PERFORM TESTS IN PLACE OF THE FIELD. THE PROCEDURE IS THE SAME AS THE FIELD.	
DENSITY CONTROL; BITUMINOUS MIXTURES NON-QA PROJECTS STD . SPEC. 401	SAMPLE MT313 CORES TEST MT212 MT313	MT313	1 TEST FOR EACH 1,000 FEET OF PAVER TRAVEL.	NOTE: DISTRICT MAY PERFORM TESTS IN PLACE OF FIELD. THE PROCEDURE IS THE SAME AS THE FIELD.	
DENSITY CONTROL; CULVERT BACKFILL STD. SPEC. 603	SAMPLE MT201 TEST MT218 MT229	MT201	1 TEST PER 6" LIFT ON EACH SIDE OF THE PIPE FOR EACH 100', A MINIMUM OF 1 TEST PER SITE.		
DENSITY CONTROL; EMBANKMENT STD. SPEC. 203	SAMPLE MT201 TEST MT204 MT218 MT229	MT201	1 TEST FOR EACH 4,000 CUBIC YARDS FOR A-1 THRU A-3 MATERIAL. 1 TEST FOR EACH 2,000 CUBIC YARDS A-4 THRU A-7 MATERIAL.	IA TESTS - 1 FOR EACH 3 MILES OR 200,000 CUBIC YARDS.	

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
DENSITY CONTROL; SURFACING MATERIAL (NON-BITUMINIZED) STD. SPEC. 301	SAMPLE MT219 TEST MT219	MT219	RESPONSIBLE FOR DENSITY CONTROL. SEE SPECIAL PROVISIONS.		
DRAINAGE; UNDERDRAINS – PLASTIC & METAL STD. SPEC 708, 709		3 FEET	1 SAMPLE FOR EACH 2,500 LINEAL FEET, MINIMUM OF 1 PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
ELECTRICAL; CONDUCTORS AND CABLES STD. SPEC. 703		3 FEET	1 SAMPLE OF EACH SIZE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
ELECTRICAL; CONDUIT - METAL AND PLASTIC STD. SPECS. 616, 703		3 FEET	ACCEPT ON CERTIFICATION & VISUAL INSPECTION FOR QUANTITIES LESS THAN 1,000 LINEAL FEET. SUBMIT 2 RANDOM SAMPLES FOR QUANTITIES OVER 1,000 LINEAL FEET (EACH SIZE).		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
EPOXY RESIN AND ADHESIVE; FOR BONDING FRESH TO HARD CONCRETE. STD. SPEC. 551		1 PINT OF EACH COMPO-NENT	1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION, SUBJECT TO TESTING WHEN REQUESTED BY THE MATERIALS BUREAU.
EPOXY; FOR BONDING HARDENED TO HARDENED CONCRETE STD. SPEC. 551		1 PINT OF EACH COMPO-NENT	1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION, SUBJECT TO TESTING WHEN REQUESTED BY THE MATERIALS BUREAU.
EXPANSION JOINT FILLER; POURED (HOT AND COLD) STD. SPEC. 707	SAMPLE RANDOM	1 QUART	1 QUART FOR EACH LOT WITH FORM 45 AND MATERIIALS CERTIFICATE.		

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
EXPANSION JOINT FILLER; PREFORMED (CORK, ETC.) STD. SPEC. 707	SAMPLE RANDOM	6"X24"	1 SAMPLE WITH MATERIALS CERTIFICATE PER PROJECT /CONTRACT.		
FENCING; BARBED WIRE, WOVEN WIRE, CHAIN LINK, HARDWARD, TIE WIRE STD. SPEC. 712	SAMPLE MT413	MT413	1 SAMPLE PER 50 ROLLS SELECTED AT RANDOM. MINIMUM OF 1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND MATERIALS BUREAU TESTING.
FENCING; STEEL FENCE POSTS STD. SPEC. 712	SAMPLE MT413	1 PER 400	1 SAMPLE PER 400 POSTS SELECTED AT RANDOM.	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND DISTRICT/AREA LAB TEST RESULTS.	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND MATERIALS BUREAU TESTING WHEN REQUESTED BY DISTRICT/AREA LAB.
FENCING; WOOD FENCE POSTS STD. SPEC. 712	NONE	NONE	VISUAL INSPECTION.		PRETESTED AT THE MILL/TREATING PLANT BY THE MATERIALS BUREAU AND ACCEPTANCE ISSUED SUBJECT TO FINAL FIELD INSPECTION.
FERTILIZER; UNDER 500 POUNDS STD. SPEC. 713	NONE	NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION.		
FERTILIZER; OVER 500 POUNDS STD. SPEC. 713	SAMPLE MT403	1 QUART	1 RANDOM SAMPLE OF THE BLENDED FERTILIZER FROM EACH SHIPMENT SAMPLED AT THE PROJECT / CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND MATERIALS BUREAU TESTING.
FIBER REINFORCED PADS BY SPECIAL PROVISION OR PLANS			DIMENSION OR WEIGHT CHECK FOR COMPLIANCE.		

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
FLY ASH; BLENDING MATERIAL) STD. SPEC. 401	MT-305	5 LB.	SEE SPECIAL PROVISIONS.		FLY ASH SOURCES ARE SUBJECT TO PRE-QUALIFICATION – ACCEPTED ON MANUFACTURER'S CERTS. AND MATERIALS BUREAU TESTING. SEE SPECIAL PROVISIONS.
GEOTEXTILES; CONSTRUCTION - WOVEN, NONWOVEN STD. SPEC. 713	SAMPLE MT421	MT421	1 SAMPLE FOR EACH 10,000 SQUARE YARDS. MINIMUM OF 1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND MATERIALS BUREAU TESTING.
GEOTEXTILES; EROSION CONTROL BLANKETS STD. SPEC. 713	NONE	NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY FIELD PERFORMANCE.		
GEOTEXTILES; GEOGRID, GEOMEMBRANE BY SPECIAL PROVISION	SAMPLE MT421	3'x ROLL WIDTH	1 SAMPLE FOR EACH 10,000 SQUARE YARDS WITH MATERIALS CERTIFICATE. MINIMUM OF 1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND MATERIALS BUREAU TESTING.
GLASS BEADS; STD. SPEC. 714	SAMPLE MT419	2 - ONE QUART CANS	2 - ONE QUART SAMPLES FROM EACH LOT, RACK OR BATCH NUMBER, UP TO 10,000 LBS., AND ONE SAMPLE FOR EACH ADDITIONAL 10,000 LBS. OR FRACTION THEREOF.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND MATERIALS BUREAU TESTING.
GUARDRAIL & MEDIAN RAIL; - HARDWARE; STD. SPEC. 705	NONE	NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND FORM 406.		RANDOM SPOT CHECKS.
GUARDRAIL & MEDIAN RAIL; - STEEL STD. SPEC. 705	NONE	NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND FORM 406.		RANDOM SPOT CHECKS.
GUARDRAIL & MEDIAN RAIL; - WIRE ROPE STD. SPEC. 705	NONE	NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND FORM 406.		RANDOM SPOT CHECKS.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
GUARDRAIL & MEDIAN RAIL: WOOD POSTS & BLOCKS STD. SPEC. 705	MT404	NONE	VISUAL INSPECTION		INSPECTED AT THE MILL/TREATING PLANT AND ACCEPTANCE ISSUED SUBJECT TO FINAL FIELD INSPECTION.
INSULATION; SPECIAL PROVISIONS OR PLANS	NONE	NONE	DIMENSION CHECK.		
MULCH; STD. SPEC. 610	MT403	MT403	1 RANDOM SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON SATISFACTORY TEST RESULTS.
NURSERY STOCK; BY SPECIAL PROVISIONS OR PLANS	MT403	MT403	FIELD INSPECTION AND ACCEPTANCE.		
PAINT; TRAFFIC STD. SPEC. 714	MT410	2 - 1 QT. SAMPLES	SAMPLE EACH LOT OR BATCH OF PAINT USED ON THE PROJECT.		ACCEPTED ON SATISFACTORY TEST RESULTS.
PAINT; NON TRAFFIC UNDER 25 GALLONS STD. SPEC. 710	NONE	NONE			
PAINT; NON TRAFFIC OVER 25 GALLONS STD. SPEC. 710	MT410	2 - 1 QT. SAMPLES	SAMPLE TO INCLUDE LABEL FROM CAN.		ACCEPTED ON SATISFACTORY TEST RESULTS.
PAVEMENT MARKING MATERIAL; EPOXY STD. SPEC. 714	MT410	1 QT. EACH OF PIGMENT & CATALYST	5 RANDOM SAMPLES PER PROJECT/ CONTRACT REPRESENTING 10 OR MORE LOTS, 1 RANDOM SAMPLE UNDER 10 LOTS, INCLUDE MFG CERT		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY RESULTS.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
PAVEMENT MARKING MATERIAL; PREFORMED PLASTIC STD.SPEC. 714	MT410	I QUART EACH OF PIGMENT & CATALYST	1 SAMPLE EVERY 1000 LINEAL FEET, MINIMUM OF 1 PER PROJECT/CONTRACT. SUBMIT ON FROM 45 WITH MANUFACTURER'S CERTIFICATION.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY RESULTS.
PAVEMENT MARKING MATERIAL; THERMOPLASTIC STD. SPEC. 714	MT410	1 LB. OF SOLID MATERIAL OF EACH COLOR	5 RANDOM SAMPLES PER PROJECT/CONTRACT REPRESENTING 10 OR MORE LOTS, 1 RANDOM SAMPLE UNDER 10 LOTS. SAMPLE AT POINT OF APPLICATION, INCLUDE MFG CERT.	5 RANDOM SAMPLES PER PROJECT/CONTRACT REPRESENTING 10 OR MORE LOTS, 1 RANDOM SAMPLE UNDER 10 LOTS. SAMPLE AT POINT OF APPLICATION, INCLUDE MFG CERT.	
PEAT MOSS; BY SPECIAL PROVISION	MT403	1 LB. SAMPLE	1 SAMPLE PER PROJECT/CONTRACT.		
PILING; FLUTED TAPER STD. SPEC. 559	NONE	NONE	VISUAL INSPECTION.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SUBJECT TO FINAL FIELD INSPECTION.
PILING; H PILES STD. SPEC. 559	NONE	NONE	VISUAL INSPECTION.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SUBJECT TO FINAL FIELD INSPECTION.
PILING; PRESTRESSED CONCRETE STD. SPEC. 559	NONE	NONE	VISUAL INSPECTION.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SUBJECT TO FINAL FIELD INSPECTION.
PILING; ROUND STEEL STD. SPEC. 559	NONE	NONE	VISUAL INSPECTION.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SUBJECT TO FINAL FIELD INSPECTION.
PILING; TREATED TIMBER STD. SPEC. 559	MT404	NONE	VISUAL INSPECTION.		INSPECTED AT MILL/TREATING PLANT AND ACCEPTANCE ISSUED SUBJECT TO FINAL FIELD INSPECTION.
PILING; UNTREATED TIMBER STD. SPEC. 559	MT404	NONE			INSPECTED AT MILL AND ACCEPTANCE ISSUED SUBJECT TO FINAL FIELD INSPECTION.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
PIPE; PVC STD. SPEC. 603		1 – 3 FT. SAMPLE	1 SAMPLE FOR EACH SIZE.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
PIPE: PRESSURE STD. SPEC. 603	NONE	NONE	VISUAL INSPECTION	ACCEPTED ON LAB REPORTS AND MANUFACTURERS CERTIFICATION.	
PIPE; WATER MAIN STD. SPEC. 603		1 – 3 FT. SAMPLE	1 SAMPLE FOR EACH SIZE.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
PLUMBING FIXTURES; BY SPECIAL PROVISION OR PLANS	NONE	NONE	FIELD INSPECTION AND ACCEPTANCE BASED ON CATALOG CUTS & BROCHURES.		
PRESTRESS ITEM; CONCRETE BEAMS STD. SPEC. 553	MT111	MT111	VISUAL INSPECTION.	INSPECTED AT POINT OF MANUFACTURE.	
PRESTRESS ITEM; CONCRETE PILES STD. SPEC. 559	MT111	MT111	VISUAL INSPECTION.	INSPECTED AT POINT OF MANUFACTURE.	
PRESTRESS ITEM; WIRESTRAND STD. SPEC. 553	MT111	4 FT. SAMPLE		SAMPLED AT POINT OF MANUFACTURE FOR PRESTRESSED ITEMS.	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
QUARRY; GEOLOGICAL RECONNAISSANCE FOR CRUSHING SITES	MT224 MT408 MT409				ACCEPTED ON GEOTECHNICAL ANALYSIS.
REINFORCING STEEL; BARS (FOR FIELD CONSTRUCTION) STD. SPEC. 711	MT414	2-30 INCH PIECES	SAMPLE ACCORDING TO TABLE 1, MT414.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
REINFORCING STEEL; BARS, EPOXY COATED (FOR FIELD CONSTRUCTION) STD. SPEC. 711	MT414 AASHTO M284	2-30 INCH PIECES	SAMPLE ACCORDING TO TABLE 1, MT414.		ACCEPTED ON MANUFACTURERS CERTIFICATION AND SATISFACTORY TEST RESULTS.
REINFORCING STEEL; BARS, PRECAST ITEMS STD. SPEC. 711	MT110 MT111	2-30 INCH PIECES	2 PIECES OF EACH SIZE FROM EACH SHIPMENT.		ACCEPTED ON MANUFACTUER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
REINFORCING STEEL; MESH – FIELD CONSTRUCTION STD. SPEC. 711	NONE	1 SAMPLE EACH LOT	1 SAMPLE FOUR LONGITUDINAL BARS WIDE AND FOUR TRANSVERSE BARS LONG. FIELD INSPECTION.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
REINFORCING STEEL; MESH (PRECAST ITEMS) STD. SPEC. 711	MT110	1 SAMPLE EACH LOT		1 SAMPLE FOUR LONGITUDINAL BARS WIDE AND FOUR TRANSVERSE BARS LONG. FIELD INSPECTION.	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
REINFORCING STEEL; WIRE ROPE STD. SPEC. 711	AASHTO T244 M30	2-4 FT. PIECES			ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
RIP-RAP; STD. SPEC. 613	NONE	NONE	ACCEPTED ON RIPRAP FORM 127.		ACCEPTED ON FORM 127 WHEN RECEIVED FROM FIELD.
ROOFING MATERIAL; BY SPECIAL PROVISION OR PLANS	NONE	NONE	ACCEPTED ON DIMENSION OR WEIGHT CHECK.		
SEEDING; STD. SPEC. 610	MT403	1 QT. EACH SPECIES			ACCEPTED ON SATISFACTORY TEST RESULTS RECEIVED FROM MSU SEED LAB. WITNESS BLENDING.
SHEET ROCK; BY SPECIAL PROVISION OR PLANS	NONE	NONE	DIMENSION CHECK.		

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
SIGNS & SIGNING MATERIAL; STD. SPEC. 704	MT406	MT406		VISUAL INSPECTION AND ACCEPTANCE IN ACCORDANCE WITH MT-406.	
SOD;	NONE	NONE	ACCEPT WITH A FIELD INSPECTION REPORT (FORM 46). SEE SPECIAL PROVISION.		
SOIL; CORROSION TESTING	SAMPLING MT207	5 LB.	SUBMIT SAMPLE WITH FORM 45.		MATERIALS BUREAU WILL ISSUE CULVERT RECOMMENDATION.
STRUCTURAL STEEL; STD. SPEC. 711	NONE	NONE	VISUAL INSPECTION.		INSPECTION ARRANGED WITH MANUFACTURER -- ACCEPTED ON MILL TEST REPORTS, SHOP DRAWINGS, ETC., SUBMITTED BY FABRICATOR.
TOPSOIL; IMPORTED STD. SPEC. 610	MT 412	2 LBS.	SUBMIT SAMPLE WITH FORM 45.		ACCEPTED ON SATISFACTORY TEST RESULTS.
TOPSOIL; SALVAGED STD. SPEC. 610	NONE	NONE			
WATER; CORROSION TESTING	SAMPLE MT207	1 QUART	1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON SATISFACTORY TEST RESULTS.
WATER-PROOFING MATERIALS; STD. SPEC. 713		1 QUART	1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON SATISFACTORY TEST RESULTS.
WEAR, CRUSHED TOP SURFACING - TYPE A & TYPE B CRUSHED BASE COURSE – TYPE A & TYPE B	MT209	60 LBS.		3 WEAR SAMPLES FOR EACH TYPE OF MATERIAL TAKEN AT RANDOM DURING THE PRODUSTION OF STOCKPILE AGGREGATES.	3 RANDOM SAMPLES FOR WEAR.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
WOOD ITEMS; TIMBER TREATED STD. SPEC. 706	NONE	NONE	VISUAL INSPECTION.		INSPECTED AT THE MILL/TREATING PLANT AND ACCEPTANCE ISSUED SUBJECT TO FINAL FIELD INSPECTION.
WOOD ITEMS; TIMBER UNTREATED STD. SPEC. 706	NONE	NONE	VISUAL INSPECTION.		INSPECTED AT THE MILL/TREATING PLANT AND ACCEPTANCE ISSUED SUBJECT TO FINAL FIELD INSPECTION.

1.0 Concrete Admixtures

1.1 Air Entraining Agents

MB-AE10	Master Builders Co.
Protex	Protex Industries, Inc.
Protex Concentrate	Protex Industries, Inc.

1.2 Water Reducer Admixtures Type A

Pozzolith 322N	Master Builders Co.
Pozzolith 122N	Master Builders Co.
Pozzolith 300N	Master Builders Co.
Protex PDA 25 DP	Protex Industries, Inc.
Protex PDA 25 XL	Protex Industries, Inc.
Pro-Krete N	Protex Industries, Inc.
PSI 400N	Gifford-Hill & Co., Inc.

1.3 Water Reducing & Retarding Admixtures Type D

Pozzolith 100R	Master Builders Co.
Pozzolith 122R	Master Builders Co.
Pozzolith 300R	Master Builders Co.
Protex PDA 25 DP	Protex Industries, Inc.
Protex PDA 25 R	Protex Industries, Inc.
Pro-Krete R	Protex Industries, Inc.

2.0 Concrete Curing Compounds

Promulsion 50 AW	Protex Industries, Inc.
LR-151 (Red Dye)	Protex Industries, Inc.
PW-3B (White)	Protex Industries, Inc.
Spec.-Cure (White)	Building Specialties
Spec.-Cure (Clear)	Building Specialties

3.0 Miscellaneous

Water Stop (bridges)	All Domestic Brands
Seed, Certified Blue Tag	Montana Seed Growers Association
Registered Purple Tag	Montana Seed Growers Association
Foundation - White Tag	Montana Seed Growers Association
Set 45	Set Products, Inc.
(Patching & Anchor Bolt Material)	
SS-1	All Domestic Brands
(Emulsified Binder for Seeding Under 10,000 gal.)	
Probond Epoxy	Protex Industries,
(ET-265 and ET-266)	Inc.
"Landglas" Fiberglass Roving	Owens Corning

METHODS OF SAMPLING AND TESTING
MT 601-04
MATERIALS SAMPLING, TESTING AND ACCEPTANCE GUIDE - INDEX
METRIC VERSION

1 Scope:

1.1 This procedure is intended as a general guide to assist in determining the basis of sampling, testing, inspection and acceptance of various materials and products commonly used on our highway projects.

2 General:

2.1 Listed in MT-601, Sections I and II, are various materials and products, the basis of acceptance for which may vary depending on the specifications, procedures or circumstances relating to these items.

3 Samples and Certification, MT-601, Section I:

3.1 In general, the department's responsibility is to assure that the material is sampled at the appropriate interval and the contractor is responsible for taking a representative sample.

3.2 Material certifications from manufacturers or suppliers are to meet MDT specifications (refer to subsection 106.03, Certification of Compliance, 1995 Standard Specifications for Road and Bridge Construction). The certification must be provided by the prime contractor, be signed by a manufacturers authorized representative, clearly identifying each lot of certified material or assemblies delivered to the work, and be submitted from the field to the Materials Bureau with a properly filled out form 46, 406 or 407. The form 46, 406 or 407 must be signed by the person making the acceptance and be submitted through the Project Manager. The contractor should be aware that without proper certification, one or the other of the following conditions will affect final acceptance:

3.2.1 The Project Manager can allow the materials to be incorporated into the work, however, he will not pay for the material until certification is made available. If the certification indicates the material does not meet MDT specifications, he can have the material removed at the contractor's expense, or accept it at a reduced price.

3.2.2 The Project Manager will not allow the material to be incorporated into the work.

3.3 In general, unless acceptance can be made on the manufacturer's certification, outside testing agency or on field inspection reports, every item used must be sampled and tested with a statement of laboratory acceptance received before it can be incorporated into the work.

3.4 Other than proven trade name products which are discussed below in article 4, all major items to be sampled and tested, and all items that may be accepted on the manufacturer's certification or label are listed in alphabetical order with instructions for sampling, testing, and acceptance in MT-601, Section I. Whenever a conflict exists between a particular test method and MT-601, MT-601 will govern.

3.5 Acceptance of an established product may be made by the field, based on the manufacturer's certification and previous satisfactory field performance. Random samples will be taken by the field and tested by the Materials Bureau at least once a construction season.

4 Trade Name Products, MT-601, Section II:

4.1 All miscellaneous trade name products listed in Section II of MT-601 can be accepted in the field based on manufacturer's certification as long as the certification complies with subsection 106.03 (Certification of Compliance, 1995 Standard Specifications for Road and Bridge Construction). Products in Section II of MT-601 have been pre-qualified by the Materials Bureau and have proven to be acceptable when used and applied in accordance with the manufacturer's recommendations. They are acceptable for use without Materials Bureau approval, but cannot be used

4 **Trade Name Products, MT-601, Section II:** (continued)

as a substitute for another product, grade, type, or class without prior written authorization by the Materials Bureau. To assure specification compliance, submit check samples to the Materials Bureau periodically for testing. Visual checks should also be made to verify the condition of the material.

4.2 In order to assure adherence to specifications, check samples should be submitted to the Materials Bureau periodically for testing. Visual checks should also be made to verify the condition of the material prior to use.

5 **Inspected Items (Outside Testing Agency or MDT Laboratory)**

5.1 Inspect all fabricated items during fabrication. Deliver this material to the project with permanent marks, identifying that it has been inspected, such as a metal tag (wood products), or a circle M stamp (RCP or CSP pipe, steel items, miscellaneous concrete products and signs). See attached for "Certification of Materials."

5.2 When properly marked materials are delivered to the project, they must be accompanied by a certification of materials report or a mill report submitted from the plant or point of manufacture, be completely filled out and signed by an authorized representative of the supplier or the designated inspection agency. A more detailed report will follow from the inspection agency including mill tests, material certification and the origin of manufacture for steel products.

5.3 Properly marked materials delivered to the project without a certification of materials or mill reports can be incorporated into the project at the Project Manager's discretion, but payment for the materials will be withheld until the reports are provided. It is the prime contractor's responsibility to ensure that proper reports are delivered to the Project Manager.

6 **Small Quantity Items:**

6.1 Projects requiring only small quantities of materials may not require standard acceptance sampling and testing. Items such as Grade C Plant Mix under 500 tons, paint under 25 gallons and minor quantities of concrete are examples. When items are designated as small quantities by the Project Manager, their acceptance will be based upon proper documentation, such as concrete mix design check, air and slump test results, aggregate gradation results, etc. The Project Manager will notify the Helena and District Labs, in writing, whenever items are accepted on this basis.

7 **Optional Samples:**

7.1 All materials incorporated into the project, whether represented by actual samples or by certification, are subject to final field inspection and acceptance by the Project Manager. He has the option to obtain more than the required minimum number of samples and to submit as many additional samples as he deems necessary to insure conformance to specifications.

8 **Samples:**

8.1 Samples of material to be incorporated into the work must be sampled by the contractor and witnessed by an MDT representative in order to be classified as **official** samples.

8.2 *Acceptance Samples* - Department personnel or an authorized representative will witness the actual samples taken by the contractor

8.3 *Quality Assurance* – Perform sampling for QA according to Montana Standard Specifications for Road and Bridge Construction for the item to be sampled. Department personnel or an authorized representative will witness samples taken by the contractor.

8 Samples: (continued)

8.4 *Independent Assurance (IA)* - The Department requires that all sampling and testing for Independent Assurance purposes be accomplished by Department personnel or authorized representatives. IA samples must be taken under the direct supervision of the Materials Supervisor or his authorized representative and must not be scheduled on such an inflexible and regular routine that its frequency can be predicted, but sufficient samples must be submitted to satisfy the frequency intended.

8.5 *Final Record (FR)* - **FR samples cannot be taken by personnel who generally do the sampling.** They must be taken by or under the direct supervision of the Materials Supervisor or his authorized representative and must not be scheduled on such an inflexible and regular routine that its frequency can be predicted, but sufficient samples must be submitted to satisfy the frequency intended. FR samples are to be taken in accordance with MT-602, section 5.

8.6 *Portland Cement* - Samples will be taken by the Materials Bureau from Montana manufacturers and suppliers. A minimum of two samples will be taken annually, more may be taken if necessary. The purpose of this sampling and testing is to establish agreement between the manufacturer's certifications and the testing done by the Materials Bureau. The Materials Bureau is inspected and accredited by the Cement and Concrete Laboratory (CCRL) as established by the National Bureau of Standards (NBS). Sampling from the project for acceptance purposes will be taken on a random basis by District personnel in accordance with MT-108. Acceptance is based upon conformity to both physical and chemical requirements listed in the specifications.

9 Forms and Reports:

9.1 Regardless of the basis of acceptance, the method of identification of all items incorporated in the project must be documented in the project records.

9.2 Most major materials to be tested have a report form designated for their exclusive use (see MT-513). These forms shall be completed as fully as possible and followed by distribution as indicated.

9.3 Materials not covered by a designated report form must be accompanied by a Miscellaneous Samples Lab Form 45. This form must be fully completed. The form must have the following information: project number, project name, date, name of the sampler, district/area, name of the product, quantity, name and address of the manufacturer, supplier and jobber, and the distribution. In the case of acceptance on the basis of certification or field inspection, a Form 46, 406 or 407 should be used. A remark must be made that a sample is not being submitted and acceptance is on the basis of an authorized prequalification program, manufacturer's certifications or labels.

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Form No. 406

CONTRACTOR'S CERTIFICATE OF COMPLIANCE
FOR NON-STRUCTURAL STEEL & IRON ITEMS
For Compliance with the "Buy America" Provision
Std. Spec 106.09 & 23 CFR 635.410

MDT FIELD ID
DATE-INSPECTOR'S INITIALS

MDT Project No._____ Project Name_____

The _____
(Name of Manufacturer/Supplier) **(Address)** **(City, State)** **(Phone)**

has furnished to _____
(Name of Contractor) **(Address)** **(City, State)** **(Phone)**

the following materials for use in the construction of the above referenced project.

MDT Bid Item No.	Product Description	Quantity	Unit LF, YD², m, m³, etc.	Applicable Specification (AASHTO, ASTM, MDT, etc.)

Submit all required documentation with this form. See the back of this form for general guidance on the "Buy America" documentation. Refer to MT 601 for sampling & testing requirements.

Contractor's Statement of Certification

☐ **Domestic Material.** I hereby certify that all manufacturing processes, including application of coating, occurred in the United States for the above listed materials and that those materials do meet all other requirements as set forth in the plans and specifications.

☐ **Non-Domestic Material.** I hereby certify that the above listed materials do meet the requirements as set forth in the plans and specifications with the exception that all or part of the manufacturing process may have occurred outside the United States. The material is considered non-domestic. The cost of this material, including delivery to the project, is _____.

By_____ Title_____
(Contractor's Name, Typed or Printed)

_____ Date _____
(Contractor's Signature)

Note: Two copies of this certificate and attachments must be submitted to the MDT Engineering Project Manager for each type of material before that material can be used on the project. The Prime Contractor is responsible for providing proper documentation to MDT, and payment will be withheld until that documentation is provided.

The form must be completely filled out by the Contractor.

Copies of this form can be obtained from the MDT Materials Bureau, 2701 Prospect Avenue, PO Box 201001, Helena, Montana 59620-1001, or phone (406) 444-6300 or (406)444-6298.

MDT Materials Bureau will conduct random checks of documentation to confirm compliance to the "Buy American" requirement (Std. Spec. 106.09 & 23 CFR 635.410), and may require mill tests at that time. All certifications must have the "domestic steel" statement on them and be signed by a representative of that company. **There is no change in Quality Assurance procedures including sampling and testing requirements (refer to MT 601).**

For Buy America documentation, steel items are divided into 4 categories. A general guide is given below. The category of an item may vary on a case-by-case basis depending on the quantity and usage. The Project Manager determines the category of an item.

1) Structural Members
- Bridge Beams
- Plate Girders
- Piling (Most Items)
- Diaphragms
- Drilled Shaft Casing

2) Fabricated Items
- Cattle guard & Wing Ends
- CSP (Corrugated Steel Pipe)
- Guard Angles
- Guardrail Posts (T-101, etc.)
- Ice Breakers
- Pedestrian Stairway
- SSPP (Struc.Stl. Plate Pipe)
- Trash Guard

3) Fabricated / Manufactured Items
- Butterfly Valves
- Ductile Iron Pipe
- Fluted Steel Piling
- Frang. Sign Post Bkwy.
- Gate Valves
- Guardrail (Most items)
- Impact Attenuators
- Irrigation Canal Gate
- Luminaire Standards and Lighting
- Sign Posts and Bases (Most Items)
- Traffic Signals and Supports

4) Manufactured Items
- Barbwire
- Conduit-Steel
- Delineator Posts
- Fencing (Most Items)
- Smooth Wire
- Stock Tank
- Water Service Line-Steel
- Welded Wire (Most Items)
- Wire Rope (Most Items)
- Miscellaneous Nuts, Bolts, etc.

Some items, like reinforcing steel, will be in different categories for different uses. In major items such as bridges, it should be considered Category 1. In other applications it could be Category 2 or 3 and sometimes Category 4.

The required Buy America documentation varies for these categories.
Category 1 requires full Mill Test Reports and documentation on all other steps in the process.
Category 2 requires this form and material test reports and certifications.
Category 3 requires this form and manufacturers certifications.
Category 4 requires this form.

For non-domestic material, documentation of the cost of the material including delivery to the project is also required.

Note: This form has been approved by FHWA for use on an interim basis. No change is being made to the "Buy America" requirements. This form is only intended to provide guidance and uniformity to the application of the existing specification. A final decision on implementation of this form will be made by June 1, 2003.

Form No. 407

CONTRACTOR'S CERTIFICATE OF COMPLIANCE FOR MISCELLANEOUS ITEMS (NON-STEEL)

MDT ID
DATE-INSPECT INITIALS

MDT Project No._____ Project Name_____

The _____
(Name of Manufacturer/Supplier) (Address) (City, State) (Phone)

has furnished to _____
(Name of Contractor) (Address) (City, State) (Phone)

the following materials for use in the construction of the above referenced project.

MDT Bid Item No.	Product Description	Quantity	Unit LF, YD², m, m³, etc.	Supplier	Applicable Spec. (AASHTO, ASTM, MDT, etc).

Product Analysis, Materials Test Reports and other required documentation must be attached to this form. Refer to MT 601 for sampling & testing requirements.

Contractor's Statement of Certification

I hereby certify that the above listed materials do meet the requirements as set forth in the plans and specifications.

By_____ Title_____
(Contractor's Name, Typed or Printed)

_____ Date _____
(Contractor's Signature)

Note: Two copies of this certificate and attachments must be submitted to the MDT Engineering Project Manager for each type of material before that material can be used on the project. The Prime Contractor is responsible for providing proper documentation to MDT, and payment will be withheld until that documentation is provided.

The form must be completely filled by the Contractor. A list of materials, which may be accepted upon receipt of this form and proper documentation, is on the back of this form.

Copies of this form can be obtained from the MDT Materials Bureau, 2701 Prospect Avenue, PO Box 201001, Helena, Montana 59620-1001, or phone (406) 444-6300 or (406) 444-6298.

Form No. 407

The following miscellaneous items may be accepted with the "Contractor's Certificate of Compliance for Miscellaneous Items" (Form 407), including appropriate attachments i.e. Certificates of Analysis, Materials Test Reports, etc. All Certifications from suppliers, fabricators, manufacturers and contractors must be signed by a representative of that company. **There is no change in acceptance, sampling or testing requirements (refer to MT 601).**

Canal Gates
Class 4 Poles
Concrete Barrier Rail
Concrete Bench
Concrete Culvert
Concrete Picnic Table
Construction Fabrics
Corrugated Aluminum Pipe
Curb-Conc. Median
Deck Seal
Delineators
Edge Drain
Fertilizer
Geo-textiles
HMWM Treatment Material
Inlets
Joint Seals-Silicon
Landscaping
Mailbox
Manholes
Median Rail-Concrete
Mulch
Plastic Pipe
PVC
Reinforced Concrete Pipe
Signs
Sod
Topsoil
Trash Receptacle
Trees & Shrubs
TT Barnpoles
Wood Fence Posts

Note: This form has been approved by FHWA for use on an interim basis. No change is being made to the "Buy America" requirements. This form is only intended to provide guidance and uniformity to the application of the existing specification. A final decision on implementation of this form will be made by June 1, 2003.

NOTE: Numbers in parentheses are page numbers

AGGREGATE:
- Bituminous Treated Base (12)
- Cement Treated Base, Stockpiled (13)
- Cement Treated Base, When Used (13)
- Concrete, During Production of Aggregate (13)
- Concrete, During Production of Concrete for Paving, QA Projects (13)
- Concrete, During Production of Concrete for all Structures (14)
- Concrete, Proposed Source (14)
- Concrete Prepared from Established Source (14)
- Concrete from a New Source (15)
- Crushed Cover Material
  - QA Projects (15)
  - Non-QA Projects (15)
- Open Graded Friction Course
  - QA Projects (16)
  - Non-QA Projects (16)
- Gravel Fill (Bedding & Filter) (16)
- Grout Sand (16)
- Plant Mix Base, Over 500 Tons(when used) (16)
- Plant Mix Base, Under 500 Tons (when used) (17)
- Plant Mix Base & Surfacing (when stockpiled)(17)
- Plant Mix Surfacing (when used)
  - QA Projects (17)
  - Non QA Projects Under 500 Tons (17)
  - Non QA Projects Over 500 Tons (18)
  - Preconstruction, Proposed Surfacing Source Samples (18)
  - Surfacing, Not Pre-Approved (18)
- Surfacing, Crushed Base Course, Crushed Top Surfacing, Selected Surfacing, Sand Surfacing
  - Non QA Over 500 tons (18)
  - Non QA Under 500 tons (19)
  - QA Projects (19)

BINDER: (19)

BITUMINOUS MATERIALS:
- Asphalt Cement & Liquid Asphalt
  - Non QA Projects Over 2,000 Gallons (19)
  - Non QA Projects Under 2,000 Gallons (20)
  - QA Projects (20)
- Asphalt Emulsions (20)
- Performance Graded Asphalt Binder - PGAB (20)

BITUMINOUS MIXTURES:
- Density Control (220
- Bituminous Surface Treatment (17)
- Mineral Filler (21)
- Plant Mix Base (21)
- Plant Mix Surfacing (21)
- Plant Mix Surfacing (Grade "B") (21)
- Plant Mix Surfacing (Grade "C") (21)
- Plant Mix Surfacing (Grade "D") (21)
- Plant Mix Surfacing (SHRP Grade) (22)
- Recycled Pavements (22)
- Seal Coat (SC) (22)

BORROW MATERIAL:
- Special Borrow (22)

BRIDGE HARDWARE:
- Nuts & Bolts (22)
- Direct Tension Indicators (22)
- Expansion Joints (22)
- Elastomeric Bearing Pads (23)
- PVC Waterstop (23)

BUILDING BLOCK & BRICK (23)

CLACIUM/MAGNESIUM CHLORIDE:
- Dust Control, Prime, De-Icer (23)

CATTLE GUARD: (23)

CEMENT:
- Portland (Montana Suppliers) (23)
- Portland (Out-of-State Suppliers) (23)
- Cement Treated Base (Mixture) (24)

CONCRETE:
- Admixtures (Established Sources (24)
- Admixtures (New Sources) (24)
- Air Test & Slump Test (Paving & Structural) (24)
- Cylinders for Statistical Acceptance (Paving) (25)
- Cylinders for Statistical Acceptance (Bridges) (25)

NOTE: Numbers in parentheses are page numbers

CONCRETE: (continued)
Cylinders for Structures Designed to
Support Loads (25)
Cylinders for Minor Structures with 50 CYS or more -
(Head walls, drop inlets, etc.) (26)
Culvert, Barrier Rail, Curb, and Other Miscellaneous Precast Items
(21)
Curing Compounds (New Sources) (26)
Curing Compounds (Established Sources) (26)
Protective Coatings for Concrete Bridge Structures
(Linseed Oil - Boiled) (27)
Water (27)

COPPER:
Water Stop (27)

CRACK SEALER: Hot Poured, Bituminous (27)

CULVERT:
Corrugated Aluminum (27)
Corrugated Steel (27)
Coatings (27)
Corrugated Underdrain (28)
Drain Tile & Drain Pipe (28)
Reinforced Concrete (28)

DENSITY CONTROL:
Bituminous Mixtures
- QA Projects (28)
- Non-QA Projects (28)
Culvert Backfill (28)
Embankment (28)
Surfacing Material, Non-Bituminized (29)

DRAINAGE:
Underdrains – Plastic & Metal (29)

ELECTRICAL:
Conductors & Cables (29)
Conduit (Metal & Plastic) (29)

EPOXY RESIN & ADHESIVE:
For Bonding Fresh to Hardened Concrete (29)
For Bonding Hardened to Hardened Concrete (29)

EXPANSION JOINT FILLER:
Poured (Hot & Cold) (29)
Preformed (Cork, etc.) (30)

FENCING:
Barbed Wire, Woven Wire,
Chain Link, Hardware, Tie Wire (30)
Steel Fence Posts (30)
Wood Fence Posts (30)

FERTILIZER:
Under 500 Pounds (30)
Over 500 Pounds (30)

FIBER REINFORCED PADS (30)

FLY ASH:
Blending Material (31)

GEOTEXFILES: CONSTRUCTION:
Woven, Non-Woven (31)
Erosion Control Blankets (31)
Geogrid, Geomembrane (31)

GLASS BEADS (31)

GUARD RAIL & MEDIAN RAIL:
Hardware (31)
Steel (31)
Wire Rope (31)
Wood Posts & Blocks (32)

HIGHWAY SIGNING (32)

INSULATION (32)

NOTE: Numbers in parentheses are page numbers

MULCH (32)

NURSERY STOCK (32)

PAINT:
- Traffic (32)
- Under 25 Gallons (Non-Traffic) (32)
- Over 25 Gallons & Not Pretested (Non-Traffic) (32)

PAVEMENT MARKING MATERIALS:
- Epoxy (32)
- Preformed Plastic (33)
- Thermoplastic (33)

PEAT MOSS (33)

PILING:
- Fluted Taper (33)
- H Piles (33)
- Pre-stressed Concrete (33)
- Round Steel (33)
- Treated Timber (33)
- Untreated Timber (33)

PIPE:
- Pressure (34)
- PVC (34)
- PVC Water Main) (34)

PLUMBING FIXTURES (34)

PRESTRESS ITEMS:
- Concrete Beams (34)
- Concrete Piles (34)
- Wire Strand (34)

QUARRY:
- Geological Reconnaissance for Crushing Sites (34)

REINFORCING STEEL:
- Bars (for Field Construction) (34)
- Bars, Epoxy Coated (for Field Construction) (34)
- Bars (Pre-cast Items) (35)
- Steel Mesh (Field Construction) (35)
- Steel Mesh (Precast Items) (35)
- Wire Rope (35)

RIP-RAP (35)

ROOFING MATERIAL (35)

SEEDING (35)

SHEET ROCK (35)

SIGNS:
- Sign & Signing Material (35)

SOD: (35)

SOIL:
- Corrosion Testing (36)

STRUCTURAL STEEL:
- New Steel (36)
- Salvaged (36)

TOP SOIL:
- Imported (36)
- Salvaged (36)

WATER:
- Corrosion Testing (36)

WATER-PROOFING MATERIALS (36)

WEAR:
- Crushed Top Surfacing, Type A & B (36)
- Crushed Base Coarse, Type A & B (36)

WOOD ITEMS:
- Timber (Treated) (36)
- Timber (Untreated) (36)
- Preservatives (37)

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; BITUMINOUS TREATED BASE – NON QA PROJECTS OVER 500 TONS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208 MT210 MT217 MT219 MT228 MT230	MT201	1 SAMPLE FOR EACH 1,500 TONS (750 CUBIC METERS) FOR THE FIRST 7,500 TONS (3,750 CUBIC METERS), AND 1 SAMPLE FOR EACH 2,500 TONS (1,250 CUBIC METERS) OVER 7,500 TONS (3,750 CUBIC METERS) THEREAFTER FOR EACH TYPE OF MATERIAL.	IA SAMPLES - 1 SAMPLE FOR EACH 50,000 TONS (25,000 CUBIC METERS) FOR THE FIRST 100,000 TONS (50,000 CUBIC METERS), THEN 1 SAMPLE FOR EACH 100,000 TONS (50,000 CUBIC METERS) THEREAFTER FOR EACH TYPE OF MATERIAL. FR - 1 SAMPLE FOR EACH 4 MILES OF 2-LANE ROADWAY.	IA SAMPLES - 1 SAMPLE FOR EACH 50,000 TONS (25,000 CUBIC METERS) FOR THE FIRST 100,000 TONS (50,000 CUBIC METERS), THEN 1 SAMPLE FOR EACH 100,000 TONS (50,000 CUBIC METERS) THEREAFTER FOR EACH TYPE OF MATERIAL.
AGGREGATE; BITUMINOUS TREATED BASE – NON QA PROJECTS UNDER 500 TONS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208 MT210 MT217 MT219 MT228 MT230	MT201	SEE SPECIAL PROVISIONS.	FR - 1 SAMPLE FOR EACH 6.4 KILOMETERS OF 2-LANE ROADWAY, MINIMUM OF 1 PER PROJECT CONTRACT.	
AGGREGATE; BITUMINOUS TREATED BASE – QA PROJECTS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208 MT210 MT217 MT219 MT228 MT230	MT202	1 SAMPLE FOR EACH 2,500 TONS (1,250 CUBIC METERS); ONE LOT = 5 SAMPLES OR APPROXIMATELY 12,500 TONS (6,250 CUBIC METERS).	1 SAMPLE FOR EACH 6 LOTS (MINIMUM OF 1 PER PROJECT). FR - 1 SAMPLE FOR EACH 6.4 MILES OF 2-LANE ROADWAY, MINIMUM OF 1 PER PROJECT/CONTRACT.	1 IA SAMPLE FOR EACH 6 LOTS, MINIMUM OF 1 PER PROJECT/CONTRACT.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; CEMENT TREATED BASE – STOCKPILED STD. SPEC. 701	SAMPLE MT216 TEST MT216	300 LB. SAMPLE EA. SOURCE OR EA. TYPE FOR MIX DESIGN	1 SAMPLE PER PROJECT/CONTRACT		TESTED AND MIX DESIGN ISSUED.
AGGREGATE; CEMENT TREATED BASE - WHEN USED STD. SPEC. 701	SAMPLE MT216 TEST MT216		1 SAMPLE FOR EACH 2,500 TONS (1,250 CUBIC METERS). 5 SAMPLES PER LOT.	1 – IA FOR EACH 5 LOTS, MIMIMUM 1 PER PROJECT/ CONTRACT.	1 – IA FOR EACH 5 LOTS, MIMIMUM 1 PER PROJECT/ CONTRACT.
AGGREGATE; CONCRETE AGGREGATE DURING THE PRODUCTION OF AGGREGATE STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT203 MT204 MT205 MT215	MT201	1 SAMPLE FOR EACH SIZE TO BE SUBMITTED TO DISTRICT/AREA LAB FOR TESTING. NOTE: CONTINUOUS SAMPLING DURING PRODUCTION TO CHECK MATERIAL.	1 SAMPLE FOR EACH SIZE.	
AGGREGATE; CONCRETE AGGREGATE, DURING THE PRODUCTION OF CONCRETE FOR PAVING - QA PROJECTS STD. SPEC. 501	SAMPLE MT201 TEST MT202 MT203 MT204 MT205 MT215	MT201	MINIMUM OF 3 SAMPLES PER DAY. NOTE: SAMPLES SHALL BE TAKEN FROM THE STORAGE BIN AT THE POINT OF MIXING OR FROM THE DEVICE THAT CHARGES THE STORAGE BIN. ANY DEVIATION FROM THIS SAMPLING PROCEDURE MUST BE APPROVED BY THE MATERIALS ENGINEER.	NOTE: THE DISTRICT/AREA LAB WILL TAKE SAMPLES IN THE EVENT THAT FIELD PERSONNEL ARE UNABLE TO SO.	IA SAMPLES - 1 SAMPLE OF EACH SIZE FOR EACH TWO LANE.1.2 KM, MINIMUM OF 1 SAMPLE FOR PROJECTS LESS THAN 1.2 KM .

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; CONCRETE AGGREGATE, DURING THE PRODUCTION OF CONCRETE FOR ALL STRUCTURES STD. SPEC. 701	SAMPLE MT201 MT201 TEST MT202 MT203 MT204 MT205 MT215	MT201	1 SAMPLE OF EACH SIZE FOR EACH 125 CUBIC METERS OF CONCRETE WITH A MINIMUM OF 1 SAMPLE FOR EACH SIZE PER PROJECT. NOTE: SAMPLES WILL BE TAKEN FROM THE STORAGE BIN AT THE POINT OF MIXING OR FROM THE DEVICE THAT CHARGES THE STORAGE BIN. ANY DEVIATION FROM THIS SAMPLING PROCEDURE MUST BE APPROVED BY THE MATERIALS ENGINEER.	1 SAMPLE OF EACH SIZE FOR EACH 125 CUBIC METERS OF CONCRETE WITH A MINIMUM OF 1 SAMPLE FOR EACH SIZE PER PROJECT. NOTE: SAMPLES WILL BE TAKEN FROM THE STORAGE BIN AT THE POINT OF MIXING OR FROM THE DEVICE THAT CHARGES THE STORAGE BIN. ANY DEVIATION FROM THIS SAMPLING PROCEDURE MUST BE APPROVED BY THE MATERIALS ENGINEER.	IA SAMPLES - AT LEAST 1 SAMPLE OF EACH SIZE OR EVERY 4TH SAMPLE OF EACH SIZE, MINIMUM OF 1 PER PROJECT/CONTRACT.
AGGREGATE; CONCRETE AGGREGATE, PROPOSED SOURCE (PIT SAMPLES) STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT203 MT204 MT205 MT209	MT201		3 – 25 KG. COMPOSITE SAMPLES FROM EACH SOURCE.	
AGGREGATE: CONCRETE AGGREGATE, FROM AN ESTABLISHED SOURCE STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT203 MT204 MT205 MT219	MT201		3 – 15 KG. SAMPLES OF FINE AGGREGATE AND 3 – 25 KG. SAMPLES OF MEDIUM AND COARSE AGGREGATE FOR EACH CONSTRUCTION SEASON FOR MIX DESIGN CHECK AND QUALITY CONTROL.	

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; CONCRETE AGGREGATE, FROM A NEW SOURCE STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT203 MT204 MT205 MT209 MT215	MT201		3 – 15 KG. SAMPLES OF FINE AGGREGATE AND 3 – 25 KG. SAMPLES OF MEDIUM AND COARSE AGGREGATE.	
AGGREGATE; CRUSHED COVER MATERIAL - QA PROJECTS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208 MT209 MT217 MT227 MT228 MT305	MT201	1 SAMPLE FOR EACH 500 TONS (250 CUBIC METERS); 1 LOT = 5 SAMPLES OR APPROXIMATELY 2,500 TONS (1,250 CUBIC METERS).	1 SAMPLE FOR EACH LOT.	1 – 70 KG. SAMPLE FROM STOCKPILE FOR DESIGN IA SAMPLES - 1 FOR EACH PROJECT/CONTRACT.
AGGREGATE; CRUSHED COVER MATERIAL - NON QA PROJECTS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208 MT209 MT217 MT227 MT228 MT305	MT201	1 SAMPLE FOR EACH 500 TONS (250 CUBIC METERS).	1 SAMPLE FOR EACH 2,000 TONS (1,000 CUBIC METERS) OR 1 SAMPLE FOR EACH SOURCE.	1 – 70 KG. SAMPLE FROM STOCKPILE FOR DESIGN IA SAMPLES - 1 SAMPLE FOR EACH PROJECT/CONTRACT.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; OPEN GRADED FRICTION COURSE - QA PROJECTS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208 MT217 MT315	MT201	1 SAMPLE FOR EACH 400 TONS (200 CUBIC METERS), 1 LOT = 5 SAMPLES OR APPROXIMATELY 2,000 TONS (1,000 CUBIC METERS). NOTE: 2 SAMPLES PER PROJECT WILL BE TAKEN FOR FRACTURE, GRADATION AND ADHESION.	400 LBS. FROM STOCKPILE FOR DESIGN. 1 – 15 KG. SAMPLE FOR EVERY 2 LOTS.	1 – 15 KG. SAMPLE PER PROJECT FOR GRADATION, FRACTURE AND ADHESION. IA SAMPLES - 2 FOR EACH PROJECT/CONTRACT.
AGGREGATE; OPEN GRADED FRICTION COURSE - NON QA PROJECTS STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT209 MT213 MT227	MT201	1 SAMPLE FOR EACH 1,000 TONS (500 CUBIC METERS). NOTE: 2 SAMPLES PER PROJECT WILL BE TAKEN FOR FRACTURE, GRADATION AND ADHESION.	180 KG. FROM THE STOCKPILE FOR DESIGN. 1 SAMPLE FOR EACH 4,000 TONS (2,000 CUBIC METERS) 1 – 15 KG. SAMPLE FOR GRADATION, ADHESION AND FRACTURE.	IA SAMPLES - 2 PER PROJECT/ CONTRACT.
AGGREGATE; GRAVEL FILL (BEDDING AND FILTER) STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT208	MT201		MINIMUM OF 1 SAMPLE PER SOURCE. TESTING AND ACCEPTANCE ISSUED BY DISTRICT/AREA LAB.	
AGGREGATE; GROUT SAND STD. SPEC. 701	SAMPLE MT201 TEST MT202	MT201		1 – 15 KG. SAMPLE FROM EACH SOURCE.	
AGGREGATE; PLANT MIX BASE, OVER 500 TONS (WHEN USED) BY SPECIAL PROVISION	SAMPLE MT201 TEST MT202 MT208 MT213 MT217 MT305	MT201 MT202	1 SAMPLE FOR EACH 500 TONS (250 CUBIC METERS) OR EVERY 2 HOURS.	1 SAMPLE FOR EACH 5,000 TONS (2,500 CUBIC METERS) (SEE MT201, 16.1) 2 SAMPLES FOR EACH PROJECT FOR VOLUME SWELL AND FRACTURE. IA SAMPLES - 1 EVERY 4TH SAMPLES, MINIMUM OF ONE FOR EACH PROJECT/CONTRACT.	1 – 225 KG LB. SAMPLE FROM THE STOCKPILE FOR DESIGN IA SAMPLES - 1 EVERY 4TH SAMPLE, MINIMUM OF ONE FOR EACH PROJECT/CONTRACT.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; PLANT MIX BASE, UNDER 500 TONS (WHEN USED) BY SPECIAL PROVISION	SAMPLE MT201 TEST MT202 MT208 MT213 MT217 MT305	SEE SPECIAL PROVISIONS	SEE SPECIAL PROVISIONS.		IA SAMPLES – MINIMUM OF 1 PER PROJECT/CONTRACT.
AGGREGATE; PLANT MIX BASE, PLANT MIX SURFACING (WHEN STOCKPILED) STD. SPEC. 701	SAMPLE MT201 TEST MT202 MT217 MT305	25 LB. FOR EACH 1,000 TONS	MINIMUM OF 5 SAMPLES PER PROJECT FOR VOLUME SWELL AND FRACTURE. NOTE: SEE SPECIAL PROVISIONS.	MINIMUM OF 5 SAMPLES PER PROJECT (AS DETERMINED NECESSARY FOR FRACTURE AND VOLUME SWELL).	MINIMUM OF 5 SAMPLES PER PROJECT (AS DETERMINED NECESSARY FOR FRACTURE AND VOLUME SWELL).
AGGREGATE; PLANT MIX SURFACING QA PROJECTS (WHEN USED) STD. SPEC. 701	SAMPLE MT201 MT202 TEST MT202 MT208 MT213 MT217 MT305	MT201 MT202	1 SAMPLE FOR EACH 600 TONS (300 CUBIC METERS), ONE LOT = 5 SAMPLES OR APPROXIMATELY 3,000 TONS (1,500 CUBIC METERS).	1 SAMPLE FOR EVERY 2 LOTS 2 SAMPLES PER PROJECT FOR VOLUME SWELL AND FRACTURE IA SAMPLES – 1 FOR EVERY 6 LOTS, MINIMUM OF 1 PER PROJECT/ CONTRACT.	1 – 225 KG. SAMPLE FROM THE STOCKPILE FOR DESIGN 2 SAMPLES PER PROJECT FOR VOLUME SWELL AND FRACTURE IA SAMPLES - 1 FOR EVERY 6 LOTS, MINIMUM OF 1 PER PROJECT/CONTRACT.
AGGREGATE; PLANT MIX SURFACING - NON QA PROJECTS (UNDER 500 TONS) STD. SPEC. 701	SAMPLE MT201 MT202 TEST MT202 MT208 MT213 MT217 MT305	MT201 MT202	SEE SPECIAL PROVISIONS.		IA SAMPLES – MINIMUM OF 1 PER PROJECT/CONTRACT.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; PLANT MIX SURFACING - NON QA PROJECTS (OVER 500 TONS) STD. SPEC. 701	SAMPLE MT201 MT202 TEST MT202 MT208 MT213 MT217 MT305	MT201 MT202	1 SAMPLE FOR EACH 500 TONS (250 CUBIC METERS) OR 1 SAMPLE EVERY 2 HOURS (SEE MT201, 16.1).	1 SAMPLE FOR EACH 5,000 TONS (2,500 CUBIC METERS) 2 SAMPLES PER PROJECT FOR VOLUME SWELL AND FRACTURE IA SAMPLES - 1 SAMPLE EVERY 4TH SAMPLE, MINIMUM OF 1 PER PROJECT/CONTRACT.	1 – 225 KG. SAMPLE FROM THE STOCKPILE FOR DESIGN 2 SAMPLES PER PROJECT FOR VOLUME SWELL AND FRACTURE IA SAMPLES - 1 SAMPLE EVERY 4TH SAMPLE, MINIMUM OF 1 PER PROJECT/CONTRACT.
AGGREGATE; SHOULDER GRAVEL, TRAFFIC GRAVEL	SAMPLE MT201 TEST MT202	MT210 MT202	MINIMUM OF 1 SAMPLE PER PROJECT/CONTRACT, RESAMPLE IF MATERIAL CHANGES. SEE SPECIAL PROVISIONS.		
AGGREGATE; PROPOSED SURFACING SOURCE SAMPLES STD. SPEC. 701	MT201	MT201		TEST FOR GRADATION, LL, PI, AND VOLUME SWELL.	ACCEPTANCE BASED ON SATISFACTORY TEST RESULTS.
AGGREGATE; SURFACING, NOT PRE-APPROVED	MT201	MT201		5 RANDOM SAMPLES PER PROJECT/CONTRACT.	ACCEPTANCE BASED ON SATISFACTORY WEAR TEST RESULTS.
AGGREGATE; SURFACING; CRUSHED BASE COURSE, CRUSHED TOP SURFACING, SELECTED SURFACING, SAND SURFACING, NON QA PROJECTS OVER 500 TONS STD. SPEC. 701	SAMPLE MT201 MT202 TEST MT202 MT208 MT210 MT217 MT219 MT228 MT230	MT201	1 SAMPLE FOR EACH 1,500 TONS (750 CUBIC METERS) FOR THE FIRST 7,500 TONS (3,750 CUBIC METERS) AND 1 SAMPLE FOR EACH 2,500 TONS (1,250 CUBIC METERS) OVER 7,500 TONS (3,750 CUBIC METERS) THEREAFTER FOR EACH TYPE OF MATERIAL.	IA SAMPLES - 1 SAMPLE FOR EACH 50,000 TONS (25,000 CUBIC METERS) FOR THE FIRST 100,000 TONS (50,000 CUBIC METERS), THEN 1 SAMPLE FOR EACH 100,000 TONS (50,000 CUBIC METERS) FOR EACH TYPE OF MATERIAL THEREAFTER.	IA SAMPLES - 1 SAMPLE FOR EACH 50,000 TONS (25,000 CUBIC METERS) FOR THE FIRST 100,000 TONS (50,000 CUBIC METERS), THEN 1 SAMPLE FOR EACH 100,000 TONS (50,000 CUBIC METERS) FOR EACH TYPE OF MATERIAL THEREAFTER. IA SAMPLES – MINIMUM OF 1 PER PROJECT/CONTRACT.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
AGGREGATE; SURFACING; CRUSHED BASE COURSE, CRUSHED TOP SURFACING, SELECTED SURFACING, SAND SURFACING, NON QA PROJECTS UNDER 500 TONS STD. SPEC. 701	SAMPLE MT201 MT202 TEST MT202 MT208 MT210 MT217 MT219 MT228 MT230	MT201	SEE SPECIAL PROVISIONS.		IA SAMPLES – MINIMUM OF 1 PER PROJECT/CONTRACT.
AGGREGATE; SURFACING; CRUSHED BASE COURSE, CRUSHED TOP SURFACING, SELECTED SURFACING, SAND SURFACING, QA PROJECTS STD. SPEC. 701	SAMPLE MT201 MT202 TEST MT202 MT208 MT210 MT217 MT219 MT228 MT230	MT201	1 SAMPLE FOR EACH 2,500 TONS (1,250 CUBIC METERS), ONE LOT = 5 SAMPLES OR APPROXIMATELY 12,500 TONS (6,250 CUBIC METERS).	IA SAMPLES - 1 SAMPLE FOR EACH 6 LOTS, MINIMUM OF 1 SAMPLE PER PROJECT/CONTRACT.	IA SAMPLES - 1 SAMPLE FOR EACH 6 LOTS, MINIMUM OF 1 SAMPLE PER PROJECT/CONTRACT.
BINDER STD. SPEC. 301	SAMPLE MT201 TEST MT201	12 KG.	SEE MT201, PARAGRAPH 8.		
BITUMINOUS MATERIALS; LIQUID ASPHALT, NON QA PROJECTS OVER 2,000 GAL. STD. SPEC. 702	SAMPLE MT302	2-1 LITER SAMPLES	2 QUARTS FROM EACH SHIPMENT OVER S TO MATERIALS BUREAU.		IA SAMPLES - FOR PROJECTS OVER 75,000 LITERS, 1 QUART FOR EACH 750,000 LITERS.

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
BITUMINOUS MATERIALS; LIQUID ASPHALT, NON QA PROJECTS UNDER 2,000 GAL. STD. SPEC. 702		NONE	CERTIFICATE OF COMPLIANCE REQUESTED.		
BITUMINOUS MATERIALS; LIQUID ASPHALT, QA PROJECTS STD. SPEC. 702		1-LITER IN METAL CONTAINER	1 - 1 LITER SAMPLE FOR EACH 500 METRIC TONS OF PLANT MIX, ONE LOT = 6 SAMPLES OR APPROXIMATELY 3,000 METRIC TONS. NOTE: FOR GRADE "C" BITUMINOUS MIXTURES REFER TO SPECIAL PROVISIONS.		IA SAMPLES - 1 SAMPLE FOR EVERY 5 LOTS TO MATERIALS BUREAU.
BITUMINOUS MATERIALS; ASPHALT EMULSIONS STD. SPEC. 702	SAMPLE MT302	2-1 LITERS SAMPLES IN PLASTIC CONTAINERS	2 – 1 LITER SAMPLES TAKEN FROM THE TANKER OR TRAILER.		I.A. SAMPLES - FOR PROJECTS OVER 75,000 LITERS., 1 SAMPLE FOR THE FIRST 375,000 LITERS. AND 1 SAMPLE FOR EACH 375,000 LITERS. THEREAFTER.
BITUMINOUS MATERIALS; PERFORMANCE GRADED ASPHALT BINDER (PGAB)	SPECIAL PROVISION	2 - 1 /2 LITER METAL CANS	SEE SPECIAL PROVISIONS		
BITUMINOUS MIXTURES; DENSITY CONTROL, QA PROJECTS STD. SPEC. 401	SAMPLE MT212 OR CORES TEST MT212 MT313	MT212 MT313	1 TEST FOR EACH 600 METRIC TONS OF MIX; LOT = 5 TESTS OR APPROX. 3,000 METRIC TONS OF MIX.	IA SAMPLES - SEE MT317.	
BITUMINOUS MIXTURES; BITUMINOUS SURFACE TREATMENTS (BST) STD. SPEC. 410			SEE "BITUMINOUS MATERIALS". SEE "CRUSHED COVER AGGREGATE".		

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
BITUMINOUS MIXTURES; MINERAL FILLER (HYDRATED LIME, FLY ASH, ETC.) STD. SPEC. 713	SAMPLE MT201 TEST MT301	MT201			1 – 2 KG. SAMPLE PER PROJECT/CONTRACT.
BITUMINOUS MIXTURES; PLANT MIX BASE BY SPECIAL PROVISION	SAMPLE MT212 OR CORES TEST MT212 MT313				225 KG. SAMPLE IS REQUIRED FOR MIX DESIGN. SAMPLE MUST INCLUDE AGGREGATE, MINERAL FILLER AND ASPHALT TYPE.
BITUMINOUS MIXTURES; PLANT MIX SURFACING GRADE "B" STD. SPEC. 401				FINAL RECORD SAMPLE - 2 CORES PER 2 LANES TAKEN IN ALTERNATING LANES AT 1 KM INTERVALS.	225 KG. SAMPLE IS REQUIRED FOR MIX DESIGN. SAMPLE MUST INCLUDE AGGREGATE, MINERAL FILLER AND ASPHALT TYPE.
BITUMINOUS MIXTURES; COMMERCIAL PLANT MIX SURFACING, BY SPECIAL PROVISION	SAMPLE MT322 TEST MT306		IGNITION OVEN (1 SAMPLE FOR EACH 500 METRIC TONS OF MIX) ACCEPTANCE SAMPLE SIZE AND FREQUENCY IS DETERMINED BY MAINT. SUPERVISOR OR ENGINEER. NOTE: SEE "SPECIAL PROVISIONS" FOR MARSHALL PROPERTIES AND PLANT PRODUCTION REQUIREMENTS.	SAMPLE AND TEST AT DISTRICT'S DISCRETION. FINAL RECORD SAMPLES - 2 CORES PER 2 LANES TAKEN IN ALTERNATING LANES AT 1/2-MILE INTERVALS.	160 KG. SAMPLE IS REQUIRED FOR MIX DESIGN, SAMPLE MUST INCLUDE AGGREGATE, MINERAL FILLER AND ASPHALT TYPE -- NOTE: MIX DESIGNS TRANSFERRED FROM OTHER PROJECTS MUST BE APPROVED BY THE MATERIALS ENGINEER.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
BITUMINOUS MIXTURES; PLANT MIX SURFACING GRADE "D" BY SPECIAL PROVISION				FINAL RECORD SAMPLES - 2 CORES PER 2 LANE MILE TAKEN AT 1 KM INTERVALS.	680 KG. SAMPLE FOR MIX DESIGN, SAMPLE MUST INCLUDE AGGREGATE, MINERAL FILLER AND ASPHALT TYPE.
BITUMINOUS MIXTURES; PLANT MIX SURFACING GRADE "S" BY SPECIAL PROVISION				FINAL RECORD SAMPLES - 2 CORES PER 2 LANE MILE TAKEN AT 1 KM INTERVALS.	680 KG. SAMPLE FOR MIX DESIGN, SAMPLE MUST INCLUDE AGGREGATE, MINERAL FILLER AND ASPHALT TYPE.
BITUMINOUS MIXTURES; RECYCLED PAVEMENTS BY SPECIAL PROVISION	SAMPLE MT201 MT316	MT316	SAMPLES FOR PROPOSED RECYCLE PAVEMENT, RECYCLED MIX DESIGN, RECYCLED PAVEMENT PRODUCTION. CONTROL SHALL BE TAKEN IN ACCORDANCE WITH MT316.	FINAL RECORD SAMPLES - 2 CORES PER 2 LANE MILE TAKEN AT 1 KM INTERVALS.	
BITUMINOUS MIXTURES; SEAL COAT (SC) STD. SPEC. 409			SEE "BITUMINOUS MATERIALS" SEE "AGGREGATE, CRUSHED COVER MATERIAL".		
BORROW MATERIAL; SPECIAL BORROW STD. SPEC. 203	SAMPLE MT201 TEST MT202 MT208	MT201	SEE "SPECIAL PROVISIONS".	DETERMINE LL, PI, SOIL CLASS AND GRADATION USING THE FIELD SAMPLE SEE "SPECIAL ROVISIONS". IA SAMPLES – ONLY IF GRADATIONS REQUIRED FOR ACCEPTANCE.	SEE "SPECIAL PROVISIONS". IA SAMPLES – ONLY IF GRADATIONS REQUIRED FOR ACCEPTANCE.
BRIDGE HARDWARE; NUTS AND BOLTS STD. SPEC. 556	SAMPLE M292 ASTM A325	M292 ASTM A325	SEE SPECIAL PROVISIONS.		ACCEPTED BASED ON MANU-FACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
BRIDGE HARDWARE; DIRECT TENSION INDICATORS BY SPECIAL PROVISION	SAMPLE ASTM F959	ASTM F959	SEE SPECIAL PROVISIONS.		ACCEPTED BASED ON MANU-FACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
BRIDGE HARDWARE; EXPANSION JOINTS STD. SPEC. 707	SPECIAL PROVISION		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND FIELD INSPECTION FORM 46.		SUBJECT TO TESTING WHEN REQUESTED.
BRIDGE HARDWARE; ELASTOMERIC BEARING DEVICES STD. SPEC. 711	AASHTO M251		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND FIELD INSPECTION FORM 46.		SUBJECT TO TESTING WHEN REQUESTED.
BRIDGE HARDWARE; PVC WATERST0P STD. SPEC. 707	ASTM D412,D746 D2240		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND FIELD INSPECTION FORM 46.		SUBJECT TO TESTING WHEN REQUESTED.
BUILDING BLOCK AND BRICK; BY SPECIAL PROVISION OR PLANS			SAMPLES WILL BE TAKEN AT RANDOM AND ACCEPTANCE ISSUED ON FIELD INSPECTION, DIST. LAB REPORTS OR MANUFACTURER'S CERTIFICATION.		
CALCIUM/MAGNESIUM CHLORIDE; DUST CONTROL, PRIME, DEICER		SAMPLE 250 ML	DETERMINE SPECIFIC GRAVITY FOR EACH DISTRIBUTOR LOAD, ACCEPT ON FORM 46. IF SAMPLE FAILS, SUBMIT FIRST SAMPLE AND ONE EVERY 400 TONS FROM DISTRIBUTOR OR WHEN TAKEN FROM DIFFERENT TANKER/RAIL CAR. SAMPLE TO MATERIALS BUREAU ON FORM 45 WITH CERT FOR TESTING.		
CATTLE GUARD STD. SPEC. 611					MATERIALS BUREAU WILL MAKE ARRANGEMENTS FOR INSPECTION.
CEMENT; PORTLAND CEMENT MONTANA SUPPLIERS STD. SPEC. 551	SAMPLE MT108	MINIMUM 7 KG.		RANDOM SAMPLES ACCORDING TO MT108.	ACCEPTANCE BASED ON MANU-FACTURER'S CERTIFICATION AND TESTS BY THE MATERIALS BUREAU. NOTE: SEE MT108.
CEMENT; PORTLAND CEMENT OUT-OF-STATE SUPPLIERS STD. SPEC. 551					MATERIALS BUREAU NEEDS TO BE NOTIFIED TO MAKE ARRANGEMENTS FOR PRETESTING.

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
CEMENT; CEMENT TREATED BASE MIXTURE STD. SPEC. 304	SAMPLE MT108 MT216 TEST MT202 MT216	2 SPECIMENS	ONE 7 DAY AND ONE 28 DAY COMPRESSION SPECIMEN FOR EACH 2 LANE MILE FOR EACH LIFT -- NOTE: SEE SPECIAL PROVISIONS FOR CEMENT CONTENT TESTING REQUIREMENTS.		
CONCRETE: ADMIXTURES - ESTABLISHED SOURCES STD. SPEC. 551	NONE	NONE			ACCEPTED ON MANUFACTURER'S CERTIFICATIONS AND SATISFACTORY FIELD PERFORMANCE.
CONCRETE: ADMIXTURES - NEW SOURCES STD. SPEC. 551		1 LITER	1 LITER FROM THE FIRST SHIPMENT WITH MANUFACTUER'S CERTIFICATION.		
CONCRETE; AIR AND SLUMP TEST (PAVING AND STRUCTURAL) STD. SPEC. 551	SAMPLE MT102 MT104 MT105 TEST MT102 MT104	MT105	ONE AIR AND SLUMP TEST ON THE 1ST THREE LOADS OF EA. CLASS FRESH CONC., THEN A MIN. OF ONE TEST FOR EA. 100 CUBIC METERS. OR PORTION THEREOF. AT LEAST ONE TEST PER DAY OF POUR IS REQUIRED. IF THE 1ST TEST SAMPLE FAILS, TESTS MUST BE PERFORMED FOR THE 2ND AND 3RD LOADS. EACH TEST WILL BE MADE USING FRESH CONCRETE.	I.A. TESTING - ONE AIR AND SLUMP TEST PER 500 CUBIC METERS OR A MIN. OF ONE PER MAJOR STR. ONE TEST PER 3.2 KILOMETERS OF 2-LANE PAVING OR MIN. OF ONE PER PROJECT/CONTRACT.	

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
CONCRETE; CYLINDERS FOR STATISTICAL ACCEPTANCE (PAVING) STD. SPEC. 551	SAMPLE MT105 MT416 TEST MT101 MT102 MT104 MT105	MT105	TWO SETS OF CYLINDERS PER LOT - SEE ARTICLE 551.03.7 OF THE MONTANA SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION FOR LOT SIZE AND SIZE OF SET.	I.A. SAMPLES - ONE PER 3.2 KILOMETERS OF 2-LANE ROADWAY WITH A MIN. OF ONE PER PROJECT/CONTRACT.	
CONCRETE: CYLINDERS FOR STATISTICAL ACCEPTANCE (BRIDGES) STD. SPEC. 551	SAMPLE MT105 MT416 TEST MT101 MT102 MT104 MT105	MT105	TWO SETS OF CYLINDERS PER LOT - SEE ARTICLE 551.03.7 OF THE MONTANA SPECIFICATIONS FOR ROAD AND BRIDGE CONSTRUCTION FOR LOT SIZE AND SIZE OF SET.	I.A. SAMPLES - ONE SAMPLE FOR EACH 500 CUBIC METERS OR A MINIMUM OF ONE FOR EACH MAJOR STRUCTURE.	
CONCRETE; CYLINDERS FOR STRUCTURES DESIGNED TO SUPPORT LOADS STD. SPEC. 552	SAMPLE MT105 MT416 TEST MT101 MT102 MT104 MT105	MT105	ONE SET OF THREE CYLINDERS FOR EACH 100 CUBIC METERS OR ANY FRACTION THEREOF FOR EACH DAY'S POUR. NOTE: THIS APPLIES TO NON-BRIDGE DESIGNED LOAD-BEARING ITEMS -- RETAINING WALLS, BUILDING FOUNDATIONS, CATTLE GUARD BASES, CULVERT FOUNDATION, AND TO CLASS AS OR BD CONRETE FOR BRIDGES.		

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
CONCRETE; CYLINDERS FOR MINOR STRUCTURES WITH 50 CUBIC YARDS OR MORE STD. SPEC. 552	SAMPLE MT105 MT416 TEST MT101 MT102 MT104 MT105	MT105	ONE SET OF THREE CYLINDERS FROM FIRST POUR WITH EA. CLASS AND ONE SET PER 100 CUBIC METERS THEREAFTER.NOTE: THIS INCLUDES SUCH ITEMS AS CURBS, SIDEWALKS, IRRIGATION STRUCTURES, FOUNDATIONS, SLOPE PROTECTION, CULVERT HEADWALLS, ECT. CYLINDERS ARE MAINLY TO VERIFY MIX DESIGN, PRIMARY ACCEPTANCE IS ON BATCH INSP., AIR AND SLUMP TESTS ON EA. POUR. ACCEPTANCE OF CONC. IN PRECAST ITEMS WILL BE ON BASIS OF FIELD CURED CYL. SEE STANDARD SPECIFICATIONS, SECTION 554.03.6.	I.A. SAMPLE - ONE PER 500 CYS. WITH A MINIMUM OF ONE SET.	
CONCRETE; CONCRETE CULVERT, STD. SPEC. 708, BARRIER RAIL, CURB AND OTHER MISC. PRECAST ITEMS STD. SPEC. 554	SAMPLE MT110 TEST MT110 AASHTO T-22		A VISUAL INSPECTION WILL BE CONDUCTED ON ITEMS DELIVERED TO THE PROJECT. NOTE: ALL ITEMS SHOULD BE STAMPED WITH A CIRCLE M (M).	THE TESTING AND INSPECTION OF CONCRETE PIPE AND ASSOCIATED ITEMS WILL BE DONE BY DISTRICT LABORATORIES WHERE CONCRETE PLANTS ARE LOCATED. SEE STANDARD SPEC. 554.	MATERIALS BUREAU WILL TEST AND INSPECT AT THE ELK RIVER PLANT IN HELENA.
CONCRETE; CURING COMPOUNDS, NEW SOURCES STD. SPEC. 551		1 LITER	SAMPLE AT RANDOM FROM FIRST SHIPMENT.		
CONCRETE; CURING COMPOUNDS, ESTABLISHED SOURCES STD. SPEC. 551		NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION. SEE ESTABLISHED PRODUCTS LIST.		

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
CONCRETE; PROTECTIVE COATINGS FOR CONCRETE BRIDGE STRUCTURES (BOILED LINSEED OIL, MINERAL SPIRITS) STD. SPEC. 551		1 LITER			ACCEPTED BASED ON MANUFACTUER'S CERTIFICATION AND SATISFACTORY TEST RESULTS. SEE NOTE 5.
CONCRETE; WATER FOR CONCRETE STD. SPEC. 551	SAMPLE MT109	1 LITER	1 LITER WHEN WATER QUALITY IS DOUBTFUL AND 1 LITER FROM EACH NEW SOURCE TO MATERIALS BUREAU.		
COPPER: WATER STOP (SHEET COPPER) STD. SPEC. 707		1-12"x12"	FABRICATION CHECK.	1 RANDOM SAMPLE FOR EACH SHIPMENT INCLUDING MANUFACTUER'S CERTIFICATION. NOTE: WEIGHT PER SQUARE FOOT AND GAUGE CHECK.	1 RANDOM SAMPLE FOR EACH SHIPMENT INCLUDING MANUFACTUER'S CERTIFICATION NOTE: NO SAMPLE REQUIRED IF TESTED BY THE DISTRICT.
CRACK SEALER; HOT POURED, BITUMINOUS PRETESTED		13 KG.	1 SAMPLE FROM THE FIRST LOT FOR PRETESTING WITH MANUFACTURER'S CERTIFICATION		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
CRACK SEALER; HOT POURED, BITUMINOUS		2 – 1 LITER CANS	1 SAMPLE FOR EACH LOT TAKEN AT THE POINT OF APPLICATION WITH MANUFACTURER'S CERTIFICATION		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
CULVERT; CORRUGATED ALUMINUM STD. SPEC. 603	MT401	MT401	VISUAL INSPECTION.	INSPECTION AT POINT OF MANUFACTURE WITH MILL TEST REPORTS SUBMITTED BY FABRICATOR.	
CULVERT; CORRUGATED STEEL STD. SPEC. 603	MT402	MT402	VISUAL INSPECTION.	INSPECTION AT POINT OF MANUFACTURE WITH MILL TEST REPORTS SUBMITTED BY FABRICATOR.	
CULVERT; COATING STD. SPEC. 603		½ KG. SAMPLE	1 SAMPLE FOR EACH LOT OR BATCH.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
CULVERT; CORRUGATED UNDERDRAIN STD. SPEC. 603		1 – 1 METER SECTION	1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
CULVERT; DRAIN TILE & DRAIN PIPE STD. SPEC. 603	NONE	NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND FIELD INSPECTION REPORT.		RANDOM SPOT CHECKS.
CULVERT; REINFORCED CONCRETE STD. SPEC. 603	MT110	NONE	VISUAL INSPECTION.	ACCEPTED ON INSPECTION REPORT AT POINT OF MANUFACTURE.	ACCEPTED ON INSPECTION REPORT AT POINT OF MANUFACTURE.
DENSITY CONTROL; BITUMINOUS MIXTURES QA PROJECTS STD. SPEC. 401	SAMPLE MT212 TEST MT313	MT212	1 TEST FOR EACH 600 METRIC TONS OF MIX; 1 LOT = 5 TESTS OR APPROXIMATELY 3,000 METRIC TONS OF MIX. FR SAMPLE - CORE ACCORDING TO MT317.	NOTE: DISTRICT MAY PERFORM TESTS IN PLACE OF THE FIELD. THE PROCEDURE IS THE SAME AS THE FIELD.	
DENSITY CONTROL; BITUMINOUS MIXTURES NON-QA PROJECTS STD . SPEC. 401	SAMPLE MT313 CORES TEST MT212 MT313	MT313	1 TEST FOR EACH 300 METERS OF PAVER TRAVEL.	NOTE: DISTRICT MAY PERFORM TESTS IN PLACE OF FIELD. THE PROCEDURE IS THE SAME AS THE FIELD.	
DENSITY CONTROL; CULVERT BACKFILL STD. SPEC. 603	SAMPLE MT201 TEST MT218 MT229	MT201	1 TEST PER 152 MM LIFT ON EACH SIDE OF THE PIPE FOR EACH 30 METERS, A MINIMUM OF 1 TEST PER SITE.		
DENSITY CONTROL; EMBANKMENT STD. SPEC. 203	SAMPLE MT201 TEST MT204 MT218 MT229	MT201	1 TEST FOR EACH 4,000 CUBIC METERS FOR A-1 THRU A-3 MATERIAL. 1 TEST FOR EACH 2,000 CUBIC METERS A-4 THRU A-7 MATERIAL.	IA TESTS - 1 FOR EACH 5 KILOMETERS OR 150,000 CUBIC METERS.	

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
DENSITY CONTROL; SURFACING MATERIAL (NON-BITUMINIZED) STD. SPEC. 301	SAMPLE MT219 TEST MT219	MT219	RESPONSIBLE FOR DENSITY CONTROL. SEE SPECIAL PROVISIONS.		
DRAINAGE; UNDERDRAINS – PLASTIC & METAL STD. SPEC 708, 709		1 METER	1 SAMPLE FOR EACH 750 METERS, MINIMUM OF 1 PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
ELECTRICAL; CONDUCTORS AND CABLES STD. SPEC. 703		1 METER	1 SAMPLE OF EACH SIZE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
ELECTRICAL; CONDUIT - METAL AND PLASTIC STD. SPECS. 616, 703		1 METER	ACCEPT ON CERTIFICATION & VISUAL INSPECTION FOR QUANTITIES LESS THAN 300 LINEAL METERS. SUBMIT 2 RANDOM SAMPLES FOR QUANTITIES OVER 300 LINEAL METERS. (EACH SIZE)		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
EPOXY RESIN AND ADHESIVE; FOR BONDING FRESH TO HARD CONCRETE. STD. SPEC. 551		1 LITER OF EACH COMPON-ENT	1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION, SUBJECT TO TESTING WHEN REQUESTED BY THE MATERIALS BUREAU.
EPOXY; FOR BONDING HARDENED TO HARDENED CONCRETE STD. SPEC. 551		1 LITER OF EACH COMPON-ENT	1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION, SUBJECT TO TESTING WHEN REQUESTED BY THE MATERIALS BUREAU.
EXPANSION JOINT FILLER; POURED (HOT AND COLD) STD. SPEC. 707	SAMPLE RANDOM	1 LITER	½ LITER FOR EACH LOT WITH FORM 45 AND MATERIIALS CERTIFICATE.		

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
EXPANSION JOINT FILLER; PREFORMED (CORK, ETC.) STD. SPEC. 707	SAMPLE RANDOM	152 X 610 MM SAMPLE	1 SAMPLE WITH MATERIALS CERTIFICATE PER PROJECT /CONTRACT.		
FENCING; BARBED WIRE, WOVEN WIRE, CHAIN LINK, HARDWARD, TIE WIRE STD. SPEC. 712	SAMPLE MT413	MT413	1 SAMPLE PER 50 ROLLS SELECTED AT RANDOM. MINIMUM OF 1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND MATERIALS BUREAU TESTING.
FENCING; STEEL FENCE POSTS STD. SPEC. 712	SAMPLE MT413	1 PER 400	1 SAMPLE PER 400 POSTS SELECTED AT RANDOM.	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND DISTRICT/AREA LAB TEST RESULTS.	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND MATERIALS BUREAU TESTING WHEN REQUESTED BY DISTRICT/AREA LAB.
FENCING; WOOD FENCE POSTS STD. SPEC. 712	NONE	NONE	VISUAL INSPECTION.		PRETESTED AT THE MILL/TREATING PLANT BY THE MATERIALS BUREAU AND ACCEPTANCE ISSUED SUBJECT TO FINAL FIELD INSPECTION.
FERTILIZER; UNDER 225 KG STD. SPEC. 713	NONE	NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION.		
FERTILIZER; OVER 225 KG STD. SPEC. 713	SAMPLE MT403	1 LITER	1 RANDOM SAMPLE OF THE BLENDED FERTILIZER FROM EACH SHIPMENT SAMPLED AT THE PROJECT / CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND MATERIALS BUREAU TESTING.
FIBER REINFORCED PADS BY SPECIAL PROVISION OR PLANS			DIMENSION OR WEIGHT CHECK FOR COMPLIANCE.		

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MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
FLY ASH; BLENDING MATERIAL) STD. SPEC. 401	MT-305	2 KG.	SEE SPECIAL PROVISIONS.		FLY ASH SOURCES ARE SUBJECT TO PRE-QUALIFICATION – ACCEPTED ON MANUFACTURER'S CERTS. AND MATERIALS BUREAU TESTING. SEE SPECIA; PROVISIONS.
GEOTEXTILES; CONSTRUCTION - WOVEN, NONWOVEN STD. SPEC. 713	SAMPLE MT421	MT421	1 SAMPLE FOR EACH 8,000 SQUARE METERS. MINIMUM OF 1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND MATERIALS BUREAU TESTING.
GEOTEXTILES; EROSION CONTROL BLANKETS STD. SPEC. 713	NONE	NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY FIELD PERFORMANCE.		
GEOTEXTILES; GEOGRID, GEOMEMBRANE BY SPECIAL PROVISION	SAMPLE MT421	1 METER x ROLL WIDTH	1 SAMPLE FOR EACH 8,000 SQUARE METERS WITH MATERIALS CERTIFICATE. MINIMUM OF 1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND MATERIALS BUREAU TESTING.
GLASS BEADS; STD. SPEC. 714	SAMPLE MT419	2 - ONE LITER CANS	2 - ONE LITER SAMPLES FROM EACH LOT, RACK OR BATCH NUMBER, UP TO 4,500 KG., AND ONE SAMPLE FOR EACH ADDITIONAL 4,500 KG. OR FRACTION THEREOF.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND MATERIALS BUREAU TESTING.
GUARDRAIL & MEDIAN RAIL; - HARDWARE; STD. SPEC. 705	NONE	NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION & FROM 406.		RANDOM SPOT CHECKS.
GUARDRAIL & MEDIAN RAIL; - STEEL STD. SPEC. 705	NONE	NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION & FORM 406.		RANDOM SPOT CHECKS.
GUARDRAIL & MEDIAN RAIL; - WIRE ROPE STD. SPEC. 705	NONE	NONE	ACCEPTED ON MANUFACTURER'S CERTIFICATION & FORM 406.		RANDOM SPOT CHECKS.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
GUARDRAIL & MEDIAN RAIL; WOOD POSTS & BLOCKS STD. SPEC. 705	MT404	NONE	VISUAL INSPECTION		INSPECTED AT THE MILL/TREATING PLANT AND ACCEPTANCE ISSUED SUBJECT TO FINAL FIELD INSPECTION.
INSULATION; SPECIAL PROVISIONS OR PLANS	NONE	NONE	DIMENSION CHECK.		
MULCH; STD. SPEC. 610	MT403	MT403	1 RANDOM SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON SATISFACTORY TEST RESULTS.
NURSERY STOCK; BY SPECIAL PROVISIONS OR PLANS	MT403	MT403	FIELD INSPECTION AND ACCEPTANCE.		
PAINT; TRAFFIC STD. SPEC. 714	MT410	2 - 1 LITER SAMPLES	SAMPLE EACH LOT OR BATCH OF PAINT USED ON THE PROJECT.		ACCEPTED ON SATISFACTORY TEST RESULTS.
PAINT; NON TRAFFIC UNDER 25 GALLONS STD. SPEC. 710	NONE	NONE			
PAINT; NON TRAFFIC OVER 25 GALLONS STD. SPEC. 710	MT410	2 - 1 LITER SAMPLES	SAMPLE TO INCLUDE LABEL FROM CAN.		ACCEPTED ON SATISFACTORY TEST RESULTS.
PAVEMENT MARKING MATERIAL; EPOXY STD. SPEC. 714	MT410	1 LITER EACH OF PIGMENT & CATALYST	5 RANDOM SAMPLES PER PROJECT/ CONTRACT REPRESENTING 10 OR MORE LOTS, 1 RANDOM SAMPLE UNDER 10 LOTS, INCLUDE MFG CERT		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY RESULTS.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
PAVEMENT MARKING MATERIAL; PREFORMED PLASTIC STD.SPEC. 714	MT410	I LITER EACH OF PIGMENT & CATALYST	1 SAMPLE EVERY 300 METERS, MINIMUM OF 1 PER PROJECT/CONTRACT. SUBMIT ON FROM 45 WITH MANUFACTURER'S CERTIFICATION.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY RESULTS.
PAVEMENT MARKING MATERIAL; THERMOPLASTIC STD. SPEC. 714	MT410	½ KG. OF SOLID MATERIAL OF EACH COLOR	5 RANDOM SAMPLES PER PROJECT/CONTRACT REPRESENTING 10 OR MORE LOTS, 1 RANDOM SAMPLE UNDER 10 LOTS. SAMPLE AT POINT OF APPLICATION, INCLUDE MFG CERT.	5 RANDOM SAMPLES PER PROJECT/CONTRACT REPRESENTING 10 OR MORE LOTS, 1 RANDOM SAMPLE UNDER 10 LOTS. SAMPLE AT POINT OF APPLICATION, INCLUDE MFG CERT.	
PEAT MOSS; BY SPECIAL PROVISION	MT403	½ KG. SAMPLE	1 SAMPLE PER PROJECT/CONTRACT.		
PILING; FLUTED TAPER STD. SPEC. 559	NONE	NONE	VISUAL INSPECTION.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SUBJECT TO FINAL FIELD INSPECTION.
PILING; H PILES STD. SPEC. 559	NONE	NONE	VISUAL INSPECTION.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SUBJECT TO FINAL FIELD INSPECTION.
PILING; PRESTRESSED CONCRETE STD. SPEC. 559	NONE	NONE	VISUAL INSPECTION.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SUBJECT TO FINAL FIELD INSPECTION.
PILING; ROUND STEEL STD. SPEC. 559	NONE	NONE	VISUAL INSPECTION.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SUBJECT TO FINAL FIELD INSPECTION.
PILING; TREATED TIMBER STD. SPEC. 559	MT404	NONE	VISUAL INSPECTION.		INSPECTED AT MILL/TREATING PLANT AND ACCEPTANCE ISSUED SUBJECT TO FINAL FIELD INSPECTION.
PILING; UNTREATED TIMBER STD. SPEC. 559	MT404	NONE			INSPECTED AT MILL AND ACCEPTANCE ISSUED SUBJECT TO FINAL FIELD INSPECTION.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
PIPE; PVC STD. SPEC. 603		1 – 1 METER SAMPLE	1 SAMPLE FOR EACH SIZE.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
PIPE: PRESSURE STD. SPEC. 603	NONE	NONE	VISUAL INSPECTION	ACCEPTED ON LAB REPORTS AND MANUFACTURERS CERTIFICATION.	
PIPE; WATER MAIN STD. SPEC. 603		1 – 1 METER SAMPLE	1 SAMPLE FOR EACH SIZE.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
PLUMBING FIXTURES; BY SPECIAL PROVISION OR PLANS	NONE	NONE	FIELD INSPECTION AND ACCEPTANCE BASED ON CATALOG CUTS & BROCHURES.		
PRESTRESS ITEM; CONCRETE BEAMS STD. SPEC. 553	MT111	MT111	VISUAL INSPECTION.	INSPECTED AT POINT OF MANUFACTURE.	
PRESTRESS ITEM; CONCRETE PILES STD. SPEC. 559	MT111	MT111	VISUAL INSPECTION.	INSPECTED AT POINT OF MANUFACTURE.	
PRESTRESS ITEM; WIRESTRAND STD. SPEC. 553	MT111	1.2 METER SAMPLE		SAMPLED AT POINT OF MANUFACTURE FOR PRESTRESSED ITEMS.	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
QUARRY; GEOLOGICAL RECONNAISSANCE FOR CRUSHING SITES	MT224 MT408 MT409				ACCEPTED ON GEOTECHNICAL ANALYSIS.
REINFORCING STEEL; BARS (FOR FIELD CONSTRUCTION) STD. SPEC. 711	MT414	2-1 METER PIECES	SAMPLE ACCORDING TO TABLE 1, MT414.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
REINFORCING STEEL; BARS, EPOXY COATED (FOR FIELD CONSTRUCTION) STD. SPEC. 711	MT414 AASHTO M284	2–1 METER PIECES	SAMPLE ACCORDING TO TABLE 1, MT414.		ACCEPTED ON MANUFACTURERS CERTIFICATION AND SATISFACTORY TEST RESULTS.

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
REINFORCING STEEL; BARS, PRECAST ITEMS STD. SPEC. 711	MT110 MT111	2-1 METER PIECES	2 PIECES OF EACH SIZE FROM EACH SHIPMENT.		ACCEPTED ON MANUFACTUER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
REINFORCING STEEL; MESH – FIELD CONSTRUCTION STD. SPEC. 711	NONE	1 SAMPLE EACH LOT	1 SAMPLE FOUR LONGITUDINAL BARS WIDE AND FOUR TRANSVERSE BARS LONG. FIELD INSPECTION.		ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
REINFORCING STEEL; MESH (PRECAST ITEMS) STD. SPEC. 711	MT110	1 SAMPLE EACH LOT		1 SAMPLE FOUR LONGITUDINAL BARS WIDE AND FOUR TRANSVERSE BARS LONG. FIELD INSPECTION.	ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
REINFORCING STEEL; WIRE ROPE STD. SPEC. 711	AASHTO T244 M30	2-1.3 METER PIECES			ACCEPTED ON MANUFACTURER'S CERTIFICATION AND SATISFACTORY TEST RESULTS.
RIP-RAP; STD. SPEC. 613	NONE	NONE	ACCEPT WITHRIPRAP FORM 127.		ACCEPTED ON FORM 46 WHEN RECEIVED FROM FIELD.
ROOFING MATERIAL; BY SPECIAL PROVISION OR PLANS	NONE	NONE	ACCEPTED ON DIMENSION OR WEIGHT CHECK.		
SEEDING; STD. SPEC. 610	MT403	1 LITER EACH SPECIES			ACCEPTED ON SATISFACTORY TEST RESULTS RECEIVED FROM MONTANA STATE UNIVERSITY SEED LAB.
SHEET ROCK; BY SPECIAL PROVISION OR PLANS	NONE	NONE	DIMENSION CHECK.		
SIGNS & SIGNING MATERIAL; STD. SPEC. 704	MT406	MT406		VISUAL INSPECTION AND ACCEPTANCE IN ACCORDANCE WITH MT-406.	
SOD;	NONE	NONE	ACCEPT WITH A FIELD INSPECTION REPORT (FORM 46). SEE SPECIAL PROVISIONS.		

NOTE: Numbers in parentheses are page numbers

MATERIAL	TEST/ SAMPLE METHOD	SAMPLE SIZE	SAMPLING, TESTING AND ACCEPTANCE ISSUED BY		
			FIELD	DISTRICT/AREA LAB	MATERIALS BUREAU
SOIL; CORROSION TESTING	SAMPLING MT207	2 KG.	SUBMIT SAMPLE WITH FORM 45.		MATERIALS BUREAU WILL ISSUE CULVERT RECOMMENDATION.
STRUCTURAL STEEL; STD. SPEC. 711	NONE	NONE	VISUAL INSPECTION.		INSPECTION ARRANGED WITH MANUFACTURER – ACCEPTED ON MILL TEST REPORTS, SHOP DRAWINGS, ETC., SUBMITTED BY FABRICATOR.
TOPSOIL; IMPORTED STD. SPEC. 610	MT 412	1 KG.	SUBMIT SAMPLE WITH FORM 45.		ACCEPTED ON SATISFACTORY TEST RESULTS.
TOPSOIL; SALVAGED STD. SPEC. 610	NONE	NONE			
WATER; CORROSION TESTING	SAMPLE MT207	1 LITER	1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON SATISFACTORY TEST RESULTS.
WATER-PROOFING MATERIALS; STD. SPEC. 713		1 LITER	1 SAMPLE PER PROJECT/CONTRACT.		ACCEPTED ON SATISFACTORY TEST RESULTS.
WEAR, CRUSHED TOP SURFACING - TYPE A & TYPE B CRUSHED BASE COURSE – TYPE A & TYPE B	MT209	25 KG.		3 WEAR SAMPLES FOR EACH TYPE OF MATERIAL TAKEN AT RANDOM DURING THE PRODUSTION OF STOCKPILE AGGREGATES.	3 RANDOM SAMPLES FOR WEAR.
WOOD ITEMS; TIMBER TREATED STD. SPEC. 706	NONE	NONE	VISUAL INSPECTION.		INSPECTED AT THE MILL/TREATING PLANT AND ACCEPTANCE ISSUED SUBJECT TO FINAL FIELD INSPECTION.
WOOD ITEMS; TIMBER UNTREATED STD. SPEC. 706	NONE	NONE	VISUAL INSPECTION.		INSPECTED AT THE MILL/TREATING PLANT AND ACCEPTANCE ISSUED SUBJECT TO FINAL FIELD INSPECTION.

1.0 Concrete Admixtures

1.1 Air Entraining Agents

MB-AE10	Master Builders Co.
Protex	Protex Industries, Inc.
Protex Concentrate	Protex Industries, Inc.

1.2 Water Reducer Admixtures Type A

Pozzolith 322N	Master Builders Co.
Pozzolith 122N	Master Builders Co.
Pozzolith 300N	Master Builders Co.
Protex PDA 25 DP	Protex Industries, Inc.
Protex PDA 25 XL	Protex Industries, Inc.
Pro-Krete N	Protex Industries, Inc.
PSI 400N	Gifford-Hill & Co., Inc.

1.3 Water Reducing & Retarding Admixtures Type D

Pozzolith 100R	Master Builders Co.
Pozzolith 122R	Master Builders Co.
Pozzolith 300R	Master Builders Co.
Protex PDA 25 DP	Protex Industries, Inc.
Protex PDA 25 R	Protex Industries, Inc.
Pro-Krete R	Protex Industries, Inc.

2.0 Concrete Curing Compounds

Promulsion 50 AW	Protex Industries, Inc.
LR-151 (Red Dye)	Protex Industries, Inc.
PW-3B (White)	Protex Industries, Inc.
Spec.-Cure (White)	Building Specialties
Spec.-Cure (Clear)	Building Specialties

3.0 Miscellaneous

Water Stop (bridges)	All Domestic Brands
Seed, Certified Blue Tag	Montana Seed Growers Association
Registered Purple Tag	Montana Seed Growers Association
Foundation - White Tag	Montana Seed Growers Association
Set 45	Set Products, Inc.
(Patching & Anchor Bolt Material)	
SS-1	All Domestic Brands
(Emulsified Binder for Seeding Under 10,000 gal.)	
Probond Epoxy	Protex Industries,
(ET-265 and ET-266)	Inc.
"Landglas" Fiberglass Roving	Owens Corning

METHODS OF SAMPLING AND TESTING
MT 602-04
ACCEPTANCE, INDEPENDENT ASSURANCE AND FINAL RECORD SAMPLING

1 Scope:

1.1 Samples are to be obtained on a random basis for materials specified in MT-601 and in specified numbers as related to yards, tons or other units of measurement.

2 Referenced Documents:

2.1 *MT Manual:*
MT 317 Procedure for Monitoring In-Place Bituminous Density and Air Voids
MT 416 Random Sampling Technique
MT 601 Material Sampling, Testing and Acceptance Guide

3 General:

3.1 *Classes of Samples and Tests:* Three classes of samples and tests are required for each project. They are "Acceptance samples and tests," "Independent Assurance samples and tests," and "Final Record samples and tests."

3.2 *Frequency of Sampling:* The frequencies at which Acceptance, Independent Assurance and Final Record samples are taken should conform in general with guide schedules determined by the State and approved by the FHWA. Rigid conformity with a frequency pattern established as a guide for general application is not expected. In general, the given frequencies are set at a minimum. As job conditions such as the uniformity of materials at the source, the methods and equipment used, and weather conditions vary, further sampling and testing can be done. The number of samples and the distribution of the locations from which they are taken should be such as to make certain that the materials incorporated and construction produced are acceptable in accordance with the plans and specifications.

3.2.1 The number of Independent Assurance and Final Record samples is given in table form in MT-601. Take Final Record samples in accordance with paragraph 6.2.1. Two exceptions to this frequency of sampling are Surfacing Aggregates and Bituminous Treated Base, each of which requires one sample per 4 miles (6.4 kilometers) of 2-lane roadway. Keep in mind that rigid conformity with the above schedules is not expected. In addition to the above, district or area engineers are free to sample any material at any time and designate the sample as an Acceptance, Independent Assurance, or Final Record sample.

4 Acceptance Samples and Tests:

4.1 These are random samples taken and tests made on a day-to-day basis to ensure the quality of materials being incorporated or proposed for incorporation into a construction project. Acceptance samples and tests are the principal means of determining whether the materials and workmanship are satisfactory or whether corrective action should be taken before the work proceeds. Acceptance samples and tests may be any of the following:

4.2 Samples of materials taken and tested at the construction site by MDT personnel who are not associated with Final Record sampling of the project.

4.3 Samples of materials taken at the construction site by MDT personnel and tested promptly at the district laboratory, area laboratory or Materials Bureau with results reported immediately to the project personnel,

4 Acceptance Samples and Tests: (continued)

4.4 Samples of materials taken by MDT or delegated inspection agency personnel at the production or processing plant, shipping point, or other source of origin remote from the project and tested promptly at the district laboratory, area laboratory or Materials Bureau with results reported immediately to the project personnel, or

4.5 Samples taken and tested by the manufacturer or supplier with test results or certificates being sent to the project and district laboratory, area laboratory or Materials Bureau personnel when shipment is made.

5 Independent Assurance Samples and Tests:

5.1 These samples are taken at random per MT-416 from materials or from construction work in progress and are not necessarily intended to check compliance with specifications. They are taken and tested to provide an independent spot check of the adequacy and effectiveness of the results obtained in Acceptance sampling and testing and to supplement these test results. If differences are discovered between Acceptance and Independent Assurance samples, it must be determined immediately why deviations exist and corrective measures taken to assure proper testing techniques. If Independent Assurance samples are to accomplish the purpose for which they are intended, they must be taken at the same place, by the same method and at the same time as routine Acceptance samples.

5.1.1 *Independent Assurance sampling will be witnessed by the district or area laboratories in accordance with the frequency shown in MT-601.* When Independent Assurance samples are taken, obtain a sufficient quantity of material to provide three separate samples made up by splitting or quartering. Test the first sample in the field, mark the second sample Independent Assurance and send to the district or area lab and mark the third sample Independent Assurance and send to the Materials Bureau. This procedure allows a direct comparison between the field, district or area lab and the Materials Bureau.

5.2 *Surfacing Sampling* - Independent Assurance surfacing samples are split in the field either into wo or three portions. In the three-portion split, one portion is tested in the field, the second in the area or district laboratory and the third in the Materials Bureau laboratory. Normally assigned personnel perform the testing in each case. The Materials Bureau portion is shipped immediately after the field and area or district laboratory results have been recorded on the accompanying laboratory forms. In the two-portion split, one portion is tested in the field and, the other is tested in the area or district laboratory. The field test results are recorded on the area or district test reports, copies of which are distributed to the Materials Bureau.

5.3 Concrete Aggregate Sampling:

5.3.1 Sampling concrete aggregate shall be done by the District Laboratory Supervisor or his designated representative.

5.3.2 Portland cement concrete aggregate Independent Assurance samples are split into two portions. One portion is tested in the area or district laboratory, the other is shipped to the Materials Bureau laboratory for testing immediately after the area or district test results have been recorded on the accompanying laboratory forms.

5.3.3 Independent Assurance samples may be selected by MDT personnel who are not associated with the taking of Acceptance samples on the project, or from samples taken for Acceptance purposes provided such samples have been taken under their observation and control. Independent Assurance samples from other than concrete cylinders or beams are to be continuously in the custody or under the observation of properly trained personnel not associated with Acceptance

5.3 Concrete Aggregate Sampling: (continued)

Sampling until they are shipped or delivered to the district laboratory, area laboratory or the Materials Bureau for testing. Exceptions to this requirement may be made when adequate measures, such as sealing the container with single use seals, are taken to protect samples between the time they are taken and the time they are delivered to the district laboratory, area laboratory or Materials Bureau for testing.

5.4 Mixtures:

5.4.1 For Portland cement concrete, bituminous concrete and other mixtures, Independent Assurance samples should be taken and tested for each individual component of a mixture for which the Independent Assurance samples were taken. Independent Assurance samples should also be taken from the completed mixtures and tested for those requirements that are applicable to the combination of materials or to the individual component materials after combining and processing. For example, Independent Assurance samples of bituminous concrete would normally be tested for percent of asphalt, gradation, and other desirable properties, such as stability, etc., while Independent Assurance samples of Portland cement concrete would be tested for slump, percent of air and strength.

5.5 Testing:

5.5.1 The testing of Independent Assurance samples is to be done at the district laboratory, area laboratory or Materials Bureau except tests such as slump tests on concrete that must be performed immediately after the sample is taken.

5.5.2 The Independent Assurance sample must be taken to the laboratory as soon as possible and tested without delay. The results obtained for each of the required tests are to be delivered promptly to the Project Manager. Results should be compared with Acceptance test results obtained on similar material and an evaluation made as to the accuracy of the Acceptance sampling and testing. Project personnel should be notified if improved procedures, closer inspection and control, and possible corrective action is required.

6 Final Record (FR) Samples and Tests:

6.1 These samples are taken at random per MT-416 from completed construction work or completed portions thereof under the same requirements and procedures as for Independent Assurance samples except that District or Area Laboratory personnel will take the FR samples.

6.1.1 Final Record samples should be taken at each individual stage of the construction work as it is completed and before it is covered or disturbed by a subsequent construction stage. This minimizes damage to finished work and facilitates the satisfactory procurement of samples. (Note 1)

6.1.2 Whenever test results indicate that significant changes have occurred in the gradation, plastic limit, or liquid limit of untreated aggregate, base, or sub-base materials (because of processing, contamination, or other reasons, after the materials were incorporated into the construction), these changes should be reported with an explanation.

Note 1 - Final Record Cores do not need to be taken on Thin Lift Overlay projects because theses types of projects are not designed for extended service life or they are not adding structural strength.

6.2 Frequency:

6.2.1 Final Record core samples on newly constructed Plant Mix Surfacing shall be taken as follows:

6.2.2 The sample frequency shall be a minimum of two cores per 2-lane mile taken at 1/2 mile intervals.

6.2 **Frequency:** (continued)

6.2.3 The cores shall be sampled in accordance with Section 2.2 and the cores will be tested in accordance to MT-317.

6.2.4 Core sample locations will be referenced to centerline.

7.3 **Purpose:**

7.3.1 Final Record core samples are taken and tests made for the following purposes:

7.3.2 To determine adequacy of pavement thickness and other construction requirements but not for the purpose of checking compliance with specification requirements. These samples are taken to verify conformity with plans and specification requirements applicable to the completed construction and not to the materials before they are incorporated into a construction project. In this respect, Final Record samples and tests serve the same purpose relative to completed construction as Independent Assurance samples and tests performed relative to work in progress and materials not yet incorporated.

7.3.3 To furnish information relative to the amounts of change in properties of the material used in the work. In this respect Final Record samples and tests are for physical research purposes to ascertain the need and basis for possible improvements in future designs and specifications.

7.3.4 To determine if corrective measures may be necessary. In this respect the Final Record samples and tests serve to indicate whether previously unknown or unsuspected conditions may exist on the project that may have a detrimental effect on the completed construction.